

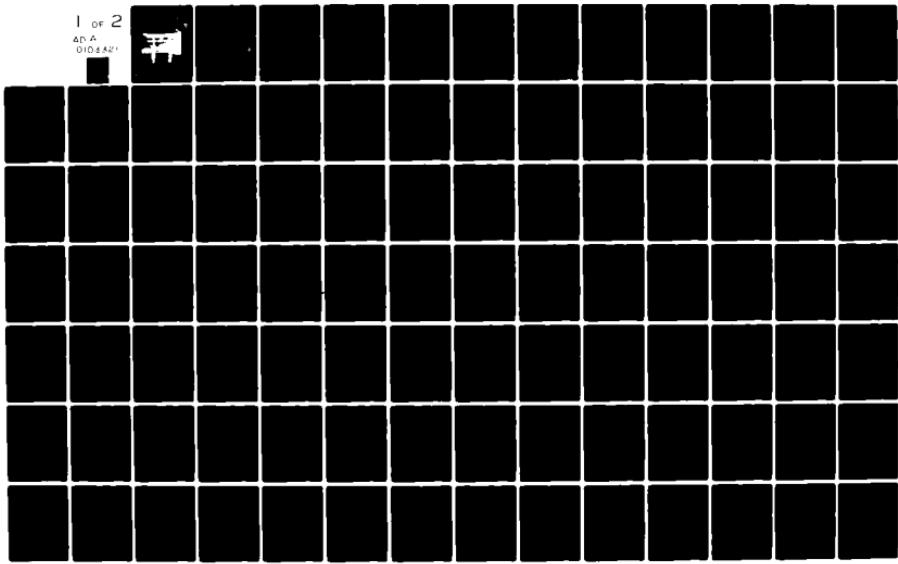
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VOL. 6, NO. 2



# SCIENTIFIC BULLETIN

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH TOKYO

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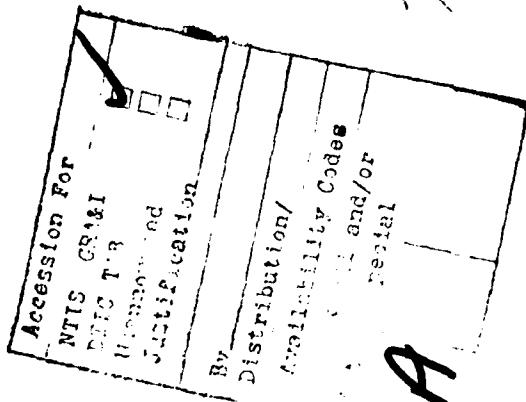
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NMR imaging  
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NMR scanners  
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convection  
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turbulence  
structural materials  
acoustic emission  
pressure vessels  
nondestructive testing  
National Research Institute for Metals  
materials research in Korea  
KIST  
KIMM  
KAIS  
POSCO

organosilylamines  
tin (II)  
lead (II)  
silicon  
dynamic behavior  
stress analysis  
metal matrix composites  
composite materials  
fatigue properties  
air breathing engines  
flight propulsion systems  
ramjet missile propulsion  
directionally solidified  
turbine blades

20. Abstract (cont.)

with certain reports also being contributed by visiting stateside scientists. Occasionally a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.



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Cover: The famous "floating Torii" of the Shinto shrine, Itsukushima, at Miyajima Island, Japan. The vermilion *Torii*, the gate symbolizing a Shinto shrine, stands about 530 feet from shore. When the tide is in, the whole shrine and torii seem as if they are floating on water. Reproduced from a photo by Erin Moore, presently a student at Stanford University.

## NATIONAL RESEARCH INSTITUTE FOR METALS REVISITED

George Sandoz

### INTRODUCTION

The National Research Institute for Metals main site at Nakameguro in Tokyo was revisited on 6 February 1981. (see *Scientific Monograph* ONR-38, p. 36, for the account of a first visit in 1977.) Director-General Toru Araki was again the principal host. A general description of NRIM was presented previously in the ONR-38 report. Moreover, in 1980 a splendid brochure describing generally the organization and activities of both the Nakameguro site and the new Tsukuba laboratories was produced by NRIM; as Araki puts it, "It has been drafted so that every reader can understand it with ease." Copies are available on request to ONR Tokyo.

Dr. Araki gave a brief overview of the activities of the various groups and these discussions were augmented in a number of cases by conversations with members of the groups. The following summarizes these discussions.

### FUNCTIONAL MATERIALS

The various materials groups focus on specific problems such as energy related electronic, high temperature, composite, shape-memory, and hydrogen storage materials. Energy related materials are of interest, both in the applications which involve new energy sources (sunshine), or which promote energy conservation (moonlight). For example, there are materials problems associated with the transport and conversion of coal to liquid and gaseous fuels (energy conservation). There are also severe problems associated with attempts to increase the efficiency of fuel-consuming heat engines such as gas turbines. Operation at even higher temperatures (energy production) is sought.

One area of intense current interest is in superconducting and cryogenic materials which may operate in a nuclear environment. One approach to the improvements of some of these materials is the development of a "perfect dispersion" of two or more insoluble phases. Since complex interactions of electromagnetic and gravitational forces normally occur during welding or melting, it is planned to conduct such experiments in space. Cooperative arrangements for use of the U.S. space laboratory by 1986 have been arranged and meanwhile experiments are being conducted using small rockets. The "perfect dispersions" sought involve alloys of Al-Pb-Bi and Cu-V, which would behave as tough materials but retain superconductivity. Perfect dispersions of compounds such as V<sub>3</sub>Ga in Cu would be produced by diffusing Ga into a perfect dispersion of V in Cu.

Another approach is the development of Laves phase V<sub>2</sub>Hf and Zr-Hf superconducting compounds fabricated into wire. Fusion reactors need a large superconducting coil which must resist high magnetic fields as well as intense radiation, especially from neutrons. The Laves phases of interest have stronger metallic character than other superconducting compounds and are, therefore, potentially tough mechanically, resistant to radiation, and tolerate higher magnetic fields before superconductivity breaks down. Efforts aim at optimization of the fabrication technique, composition and structural parameters of the Laves phases.

Other interests are in the use of superconductors for power transmission lines. Such lines carry alternating current, which rules out NbTi. Fine structure Nb<sub>3</sub>Ge and Nb<sub>3</sub>Si are

attractive from this standpoint and show a critical temperature over 20.4K, the temperature of liquid hydrogen (therefore helium is conserved). It is hoped to combine the transport of liquid hydrogen as a fuel with the transfer of power.

## EB WELDING

The EB welding group is engaged in two activities. First, there are efforts to establish welding conditions which produce defect-free welds. At present fundamental data are being gathered toward the welding of heavy-gage materials for pressure vessels. Items under study include:

- movements of the molten metal,
- solidification of the molten metal after the EB passes,
- mechanisms of defect formation, and
- effects of position (horizontal, vertical, etc.).

Some recent papers describe these activities, as cited below:

1. "Investigation on Factors Influencing Weld Penetration Depth in Electron Beam Welding," H. Irie, T. Hashimoto, and M. Inagaki, *Trans. NRIM*, Vol. 21, No. 2 (1979), p. 58.
  - The melting process by an electron beam is intermittent and consists of a drilling process and a process involving blowing off of molten metal.
2. Power Density of Electron Beam in an Electron Beam Welder," H. Irie, T. Hashimoto, and M. Inagaki, *Trans. NRIM*, Vol. 22, No. 2 (1980), p.95.
  - An apparatus to measure the radial current density distribution in the electron beam was developed. The radial distribution is important because the power density of the beam influences the welding process.
3. "Detective Method of Electron Beam Welding Process," H. Irie, T. Hashimoto, and M. Inagaki, *Trans. NRIM*, Vol. 22 , No. 3 (1980), p.167.
  - Copper electrodes or "probes" were used to explore electric currents emitted over metal melted by electron beams. Both ac and dc components at various frequencies were detected. Weld characteristics and defects could be correlated with the electrical behavior, e.g., spikes could be correlated with a low-frequency ac component.
4. "Feedback Control of Welding Parameters for Improvement of Electron Beam Weld," H. Irie, S. Tsukamoto, T. Hashimoto, and M. Inagaki, Proc. International Conference on Welding Research in the 1980's, October 27-29, Osaka Japan.
  - The use of feedback control of the electron beam current on beam oscillation was moderately successful in minimizing defects in steel 30 mm thick.

The second activity of the EB welding group is the space metallurgy described previously.

## NONDESTRUCTIVE EVALUATION

The NDE work observed involved crack measurement by eddy current, magnetic, and ultrasonic techniques. The ultrasonic technique features the so-called crack tip echo, a refracted beam. An intense, focused probe is achieved through use of a spherically curved transducer. Development of the equipment for use in very thick plate is currently under study.

The magnetic crack detector apparently measures the size of a crack. The Hall effect as influenced by the crack is picked up by a small sensor. The eddy current sensor is used by NRIM to detect cracking in stainless steel tube specimens which contain high temperature (220-300°C) water under pressure (150 Kg/cm<sup>2</sup>) and which are also subject to cyclic tensile loading.

## ENVIRONMENTAL EFFECTS

An interesting project is underway in which the effects of insufficient penetration during welding on subsequent behavior during corrosion fatigue is studied. The tests on SM 50 steel welds show a deleterious effect as measured by shifts in S-N curves obtained for a saltwater environment. It is intended to study crack growth effects in saltwater next. In these studies crack growth rates will be measured *in situ* using an ultrasonic method.

There are many tests being conducted on materials for reactor applications. These involve stainless steels under a variety of conditions of stress in high temperature water of specific purity. Stress corrosion cracking requires critical combinations of material character, environment, and stress. The work so far indicates that a low carbon content in austenite stainless steel is desirable. The effects are strain rate sensitive also.

For pressurized water reactors, tests are conducted on Inconel 600 using tube specimens containing water at 350°C internally and immersed in water at 250°C externally. The results indicate that an acidic condition, which may develop in crevices, is a prelude to SCC problems.

In all of these tests the purity of the water is critical. Therefore, the oxygen concentration is carefully controlled for study and all tests are conducted in water purified of chloride ion.

## POWDER METALLURGY

There is a spectrum of activities at NRIM associated with powder metallurgy. Powders, including alloy powders, are made by an atomizing method. Most of the usual powder metallurgical techniques are studied. In addition, there is work on such processes as sinter-forging, which involves reheating in the die in a hot-stage forge.

There is also work on powder rolling. The process has potential for providing thin sheets of material otherwise difficult to process. An example would be Sendust, a brittle magnetic material.

For the future, there is much interest in producing high temperature alloys - Ni and Co base alloys dispersion strengthened. There is interest in utilizing powder metallurgical techniques to incorporate ceramic oxides such as Y<sub>2</sub>O<sub>3</sub> in such alloys. This oxide is stable in a metal matrix at high temperatures.

Following the above visit to NRIM, Nakameguro site, the Tsukuba Materials Development Group was visited on 26 February. Some of the work on electronic materials high strength-high temperatures materials and on nuclear materials were further discussed. A first-rate facility for these studies is being completed at this time. Some interesting work on the development of high strength steels resistant to sea water is being initiated. It is desired to develop a strong (250 Kg/mm<sup>2</sup>), weldable and tough steel resistant to corrosion and corrosion fatigue in sea water.

In summary, NRIM remains a center of excellence in metallurgical research which anticipates future problems and needs.

A listing of current NRIM research projects is appended.

## APPENDIX I CURRENT PROJECTS AT NRIM

### PROJECT RESEARCHES

#### Special Researches

Subject	Leader
Metal hydrides for hydrogen storage	Yasuo Sasaki
Developments of superconducting and cryogenic materials	Kyoji Tachikawa
Development of sea water resistant high strength steels	Iku Uchiyama
Corrosion and its prevention of metallic materials in natural environment of Asia	Masatoshi Suzuki

#### Atomic Energy

Subject	Leader
Superconducting materials for fusion reactor magnet	Kiyoshi Inoue
Structural materials for fusion reactor	Norio Kainuma
Effect of neutron irradiation on the mechanical properties of stainless steels	Haruki Shiraishi
Studies on the low-Z material coatings for a first wall of fusion reactor	Masatoshi Okada
Corrosion fatigue and stress corrosion of metallic materials for water-cooled reactors	Masatoshi Suzuki

#### Data Sheet of the Strength of Materials

Subject	Leader
NRIM fatigue data sheets	Masao Kanao
NRIM creep data sheets	Renpei Yoda

Specially Coordinated Researches of STA

Subject	Leader
Fatigue behavior of materials at cryogenic temperatures	Iku Uchiyama
Study on separation technique of biocomponents and cell components	Osamu Watanabe
Improvement of soundness and reliabilities of composites with fiber reinforcements	Osamu Watanabe
Designated Researches	
Subject	Leader
Study on development of ultrahigh strength steel	Yoshikuni Kawabe
Melting of reduced iron powder by plasma arc furnace	Minoru Tanaka
Studies on the melting and smelting process	Shiro Yoshimatsu
Study on the recycle system of clean mold process	Toshihisa Makiguchi
Weld defects and environment strength of structural steels	Michio Inagaki

Researches Financed by Other Government Agencies

Subject	Leader
Research and development of advanced gas turbine	Michio Yamazaki
Direct ironmaking process using high temperature reducing gases	Renpei Yoda
Recovery and elimination of metals in waste water by suspension electrolysis	Ryoji Watanabe Minoru Tanaka

**SURVEY RESEARCHES**

Subject	Leader
Survey on materials for coal conversion plants	Michio Yamazaki
Investigation and study on un-ion beam creep test	Haruki Shiraishi
Development of multiperformance elements by complex processing technology	Isao Okane

**CURRENT RESEARCHES**

Materials Development	
Subject	Leader
Physical properties of metal surfaces	Hiroshi Nose
Electronic states and diffusion of hydrogen in metals	Makoto Okochi

Survey on X-ray observations of void formation in nuclear materials	Tokuo Tsujimoto
Preparation and characterization of ternary semiconductors and magnetic compounds	Katashi Masumoto
Instrument data processing system and its application	Iwao Yamamoto
Improvement in the properties of low alloy steels by heat treatment	Hirooki Nakajima
Improvement for environmental embrittlement of stainless steel	Takao Aoki
Size effect in fracture testing	Tomoyuki Takeuchi
Strengthening of materials by directional martensitic transformation	Setsuo Kajiwara
Textures and their applications for metals and alloys having high melting point	Yukio Ohba
Development of titanium and zirconium alloys and its applications	Toshiyuki Suzuki
High strength aluminum and magnesium alloys	Shigeru Matsuo

#### Materials Development

Subject	Leader
Magnetic materials and electric contact materials	Hiroshi Maeda
Studies on the improvement of embrittlement of molybdenum and its alloys	Masatoshi Okada
Study on corrosion and strength of heat resisting alloys in various environments	Tadashi Suzuki
Study on the hydrogen environment embrittlement of high strength steels	Ei-ichi Furubayashi

#### Process Metallurgy

Subject	Leader
Blowhole formation in metals during solidification	Masahiro Uda
Chemical state analysis of precipitates in heat resisting alloys	Ichiro Morimoto
Application of radioisotopes to metallurgy	Yoichi Maebashi
Trace analysis and multielement analysis of metals	Emiko Sudo
Improvement in reactivity of raw materials for iron making	Akira Ohba
Recovery of lithium from its dilute solution	Takeji Takeuchi
Improvement of properties and decrease of nonmetallic inclusion in steel	Koki Gunji
Continuous process of lead copper extraction	Hiroshi Kametani
Continuous process for Ti production	Hiroshi Kametani

## Metal Processing

### Subject

Manufacture of permanent mold by compound processing  
 Production of composite metal sheet by cold rolling  
     at high reduction  
 Hot extrusion process of brittle materials under  
     high pressures  
 Improvement in performance of sintered alloys  
 Some metallurgical considerations on improvement of  
     weld interface  
 Weld cracking in arc welded joints  
 Study of pressure welding parameters  
 Electron beam welding procedure with welding positions  
 Cold cracking susceptibility of carbon manganese  
     structural steels in underwater wet welding  
 Behavior of carbon in surface segregation and  
     oxidation in heat resisting alloys  
 Corrosion prevention of aluminum and steel by  
     combined surface treatments  
 Corrosion and protection of metals in recirculating  
     water system

### Leader

Masao Kikuchi  
 Tasuku Dendo  
  
 Atsushi Oguchi  
  
 Tooru Takeda  
 Isao Okane  
  
 Akira Okada  
 Kinji Tanuma  
 Micho Inagaki  
 Sadao Fukushima  
  
 Kazuyoshi Nii  
  
 Toshiro Fukushima  
  
 Tetsuo Fujii

## Material Strength

### Subject

Preparation and mechanical properties of dispersion  
     strengthened alloys  
 Process of crack formation in iron alloys  
 Fractographic study of fatigue failure  
 Fatigue crack initiation from the toe of the weld  
     and its growth behavior  
 Environmental fatigue property of metals and fatigue  
     property of metals under combined loading  
 Process of fatigue failure at elevated temperature  
 Stress relaxation and varying stress creep on  
     high-temperature steels

### Leader

Sennosuke  
 Takahashi  
 Takashi Yasunaka  
 Satoshi Nishijima  
 Etsuo Sasaki  
  
 Koichi Tanaka  
  
 Masao Kanao  
 Chiaki Tanaka

## FRESH WINDS IN THE LAND OF MORNING CALM

George Sandoz

### INTRODUCTION

Several materials research and development and industrial activities were visited in Korea, 8-14 March, 1981.

### KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY (KIST)

The first visit was with the Korea Institute of Science and Technology (KIST) in Seoul. Principal host and guide was Dr. In-Hoon Choi, a graduate of the University of Southern California under Dr. Young Kim, currently the Scientific Director of the Office of Naval Research, Tokyo. Others visited were Dr. Il Koo Kang, head of the Nonferrous Metallurgy Laboratory, Dr. Sung Do Jang, manager of the Materials Science Department, Dr. Suk-Ki Min, head of the Semiconductor Materials Laboratory and Dr. Sun-Chae Maeng, manager of the Metallurgy and Metallurgical Engineering Research Department. These visits followed a formal lecture on some Office of Naval Research (ONR) and Naval Research Laboratory (NRL) materials research.

In the limited time available, only a hasty tour could be conducted and the discussions were also brief. Dr. Kang presented slides on the general history and activities of KIST. Dr. Kang is personally conducting research on magnetic and electric alloys. For example, he is interested in heat-resistant (to 90 °C) aluminum cable to avoid sagging at high current. He is trying to achieve this by alloying judiciously with Zr to minimize increases in electrical resistance. Another current interest of Dr. Kang's is in amorphous magnetic alloys. He seeks to produce high saturation and low permeability materials in the Fe-B system.

In the Materials Science Department, Dr. Jang is concentrating on ceramic materials and Dr. Choi on semiconductors. For example, the techniques for growing large silicon single crystals are highly developed at KIST. A single crystal 3 inches in diameter and approximately a foot long had been grown which appeared to be symmetrical and otherwise perfect in all aspects.

There was great interest in the ONR and NRL work in ceramics. The Materials Science Research Department is involved in an assortment of projects-optical fiber, magnetic tape materials, permanent magnet materials, piezoelectric elements, dielectrics, and insulators. In addition, there is intense interest in structural, thermal shock resistant ceramics, process improvement of ceramics, development of new ceramics from local resources, catalysis, etc. Finally, there is activity in glass, glass-ceramics, and composite ceramic materials.

Dr. Maeng told of work on electronic and electrical metallic materials, materials for use in chemical and power plants, the development of tungsten and rare-earth applications (these materials are found in Korea) and the improvement of heat resisting steels.

There are a number of other laboratories working in areas closely connected with materials research and concerns. These are:

- Polymer Science Research Department,

- Chemical Engineering Research Department,
- Applied Chemistry Research Department,
- Process Engineering Research Department,
- Electrical and Electronics Engineering Research Department,
- Mechanical Engineering Department,
- Machinery and Equipment Development Department,
- Decision Machinery Technology Center and,
- Foundry Technology Center.

All of these departments and centers appear to be doing significant development work. Examples of some recent papers published in the materials, metallurgy, and CAD/CAM areas includes the following:

- "Hydrophylic Polymer Membranes Containing Carboxylic Groups-I," Un Young Kim, *European Polymer Journal*, (4), 325 (1979).
- "A Study on Combustion Characteristics of Solid Fuels (I)," Won-Hoon Park and Seong Ahn Hong, *Journal of The Korea Institute of Chemical Engineers* 16 , (6), 389-396 (1979).
- "Molecular Theory of Superplastic Deformation," Chang Hong Kim and Taikyue Ree, *Journal of the Korean Chemical Society*, 23, (4), 217-236 (1979).
- "Geometric Modeling; the Interface Between CAD and CAM," Won Lyang Chung, *Journal of the Korea Information Science Society* 6 , (4), 1-12 (1979).
- "A Review of the Reaction Mechanism and Reactor Characteristics in Coal Gasification Processes," Seung Man Yang and Won Hoon Park, *Journal of the Korean Institute of Chemical Engineers* 17, (4), 241-271 (1979).
- "Manufacturing Method of Low-loss Silica-based Optical Fiber-MRT method," Hong Jo Lo, *The Journal of Review, Korea Institute of Electronics Engineers*, 6 , (3), 12-19 (1979).
- "A Review of High Strength Titanium Alloys," Won Young Chung and Young Koo Yun, *Journal of the Korean Institute of Metals*, 18 , (1), 19-27 (1979).
- "A Review of Light Alloys for the Use of Airplane," Koo Il Kang, *Journal of the Korean Institute of Metals*, 18 , (3), 12-19 (1979).
- "Serrated Flow in the Austenitic State of 300 Grade Managing Steel," In Seop Kim, *Metal Science Journal*, 13 , (12), 691-695 (1979).
- "Application of the Regular Solution Model for the Equilibrium of Distribution of Oxygen between Liquid Iron and Steel Making Slags," Ban-Ya Shiro and Jae-Dong Shim, *Metal*, 65 , (4), 185 (1979).
- "Study on Properties of Self-fluxing Sinter at Various Levels of Basicity and With Varying Amounts of Coke," Jae Dong Shim, Akira Ohba, and Minoru Tanaka, *Trans. National Res. Inst. Metals*, 22 , (1), 31-37 (1979).
- "Effects of Remelting of Tool Steels by the Electroslag Remelting Process," Ju Choi, Suh Sang Hee, and Hyung Sup Choi, *Journal of the Korean Institute of Metals* 17, (5), 387-394 (1979).

- "Effects of Two Step Solution Treatment and Phosphorus Addition on the Creep Rupture Properties of High Manganese Steel," Choi Hyung Sup, Jae Seok Ryu and Ju Choi, *Journal of the Korean Institute of Metals*, 17, (6), 498-506 (1979).

The funding for KIST has been increasingly assumed by the government, according to Dr. Kang. Smaller industries do not favor long-term investments in research and development, and the larger industries in Korea have relied on foreign technology. The government is encouraging fewer but long-term, large-scale research efforts of national importance. Among these are domestic developments of industrial materials and efforts to solve resource and energy shortages. There is essentially zero work that may be classified as primarily basic research. The total KIST staff numbers over 1000 of which over half are scientists or technicians. Almost 100 have doctorates, mostly from outstanding Western universities. The funding (in 1979) amounted to 7.75B won total (\$11 million) of which 1.45B won (\$2 million) was in metals and materials.

It is interesting and perhaps significant that KIST has been operating for little more than a decade. President Johnson and the President of South Korea suggested the establishment of KIST in 1965. After agreements were made for financial assistance and cooperation in 1966, the dedication ceremony finally took place in October 1969. The physical plant is now quite impressive as are the capabilities of the scientific staff. An air of progress and optimism pervades and the morale is exceptionally robust.

#### KOREA ADVANCED INSTITUTE OF SCIENCE

The Korea Advanced Institute of Science (KAIS) is physically adjacent to KIST, and the two institutions have recently united organizationally. KAIS is a graduate school of applied science and engineering established also about a decade ago with the encouragement and support of the United States. The mandate of the school is "produce for Korean industry a supply of engineers and applied scientists who combine high ability with advanced training toward the technological needs of modern industry."

The institute, which opened in 1973, was intended to overcome deficiencies in technical education in Korea at that time. It was detached from the Ministry of Education to free it from "stifling rules and regulations." It was, however, supported, and therefore to a degree controlled, by the almost equally new Ministry of Science and Technology. The basic approach to achieve modernization was to eschew old methods-excess memorization, little laboratory experience and, worst of all, lack of contact with the technical world outside of the campus and outside of Korea. Professors with up-to-date training were also scarce.

The results of this operation bootstrap have been rather successful, and there are now several hundred full-time students and a well-trained faculty, most of whom have studied abroad. In fact, a substantial majority have a doctorate from a distinguished Western university. For example, eight members of the Faculty of Materials Science have been awarded doctorates from Steven Institute of Technology (1968), Harvard University (1968), Stanford University (1970 and 1971), North Carolina State University (1970), Massachusetts Institute of Technology (1971), Colorado School of Mines (1974), and Technische Hochschule in Aachen (1975). These degrees are in physical metallurgy, powder metallurgy, electronic materials, ceramics, general metallurgy, and mechanical metallurgy. There are also a number of adjunct professors from abroad.

The students are highly select among Korean graduate students for the excellent reasons that the students are supported entirely by the Ministry of Science and Technology,

and are, moreover, either completely or in part excused from military obligations. But only about one of seven applicants manage to pass the stiff entrance examination.

Principal host at KAIS was Dr. Soo Woo Nam whom I met at the JIMS-2 Conference on Hydrogen Embrittlement, Minulsami Spa, in 1979. Dr. Nam indicated that KAIS has first-rate faculty and students, but is only now accumulating the equipment it needs to perform many types of advanced research. Thus, the unification with KIST should prove beneficial because KIST appears to be relatively well-equipped.

Nam's research interests are fairly wide. Currently he is studying creep of aluminum alloys under constant stress, cyclic stress, and constant load conditions. Two papers on this work appear in the *Journal of the Korean Institute of Metals*, 18, (4), p.325 and (5), p.397, (1980). They deal with creep mechanisms as related to effective stress and dislocation structure.

Somewhat earlier Nam and his colleagues studied hydrogen entry and embrittlement of alpha non and Fe-13% M steel. One paper dealt with the mechanisms which describe the effect of poisons on hydrogen entry. The data appear to show that poisons such as As may reduce the cathode area of iron by forming an insulating amorphous layer. This causes the current in the uncoated areas to increase and produce higher hydrogen concentrations in these areas, with consequent cracking (see *JKIM* 15, (1), [1977]).

The embrittlement mechanism for the Fe-13Mn alloy was concluded to involve hydrogen-induced martensitic transformation with or without the imposition of external stress. This observation was concluded to support planar pressure theory of embrittlement (see *JKIM* 15, (6), 559, [1977]).

In the wear or tribology area, Nam and others have published an interesting paper on the abrasion wear resistance of Ni-hard cast iron. Wear resistance is improved if untransformed retained austenite is present, even though such irons are softer than irons which have been treated to convert the austenite to bainite. Thus the transformation at the abrading surface is integral to the wear resistant properties (see *JKIM* 18, (3), 209 [1980]).

Finally, Nam has studied the effects of AlN on the mechanical properties of low-carbon steel. Two conditions were studied: one, the AlN was stoichiometric and two, there was an excess of aluminum. Finer AlN precipitates were observed when the composition is stoichiometric. This produces finer grain size and enhances precipitation hardening which improves tensile strength and ductility. (see *JKIM* 19, (1), 5 [1981]).

The majority of the papers published by authors from KIST and KAIS appear in Korean journals. While this in some cases may indicate language, cultural, or even professional limitations, there is evidence that global communication is on the increase. For example, Professor D. N. Yoon (Ph.D. in powder metallurgy, Harvard, 1968) of the Faculty of Materials Science has been publishing in *Metallurgical Transactions* (*Met. Trans. A*, [1978], 9A ; *Met. Trans. A*, [1981], 12A) and in *Acta Met* (*Acta Met* [1979], 27).

#### KOREAN INSTITUTE OF MACHINERY AND METALS (KIMM)

The Korean Institute of Machinery and Metals is located in Changwon. The general purpose of their institute is to promote the Korean machinery and electronics industries. Included are precision machinery and chemical-metallurgical interests. The institute does

this through research and development, testing and inspection, technical innovation, and providing training for technical manpower. It apparently also serves as liaison between Korean machinery buyers or sellers and foreign countries, with the purpose of assuring Korea the best in imports of machinery and the maximum in export opportunities.

The research and development conducted at KIMM is as yet limited. The policy is to integrate R&D with the testing and inspection (T&I) activities which involve domestic firms. The R&D is directed to the problems T&I activities reveal.

There are a number of well-trained engineers and scientists at KIMM, with the usual degrees from America or Europe. It was stated that the staff is being increased to provide, in the future, greater emphasis on R&D.

A brief tour of the institute laboratories was made, and an assortment of testing apparatus was seen. For example, the surface treatment laboratory includes facilities for coating, plating, and inspection, and a rather elegant climatic test chamber featuring temperature range of -50°C to 100°C, relative humidity range of 5 to 99 percent and the capability for simultaneous application of IR or UV radiation. There are devices also for measuring coating thickness, porosity, and brightness. In addition, there is an assortment of chemical analytical equipment.

The materials test laboratory featured a variety of push-pull and flexural fatigue machines, some fitted for tests up to 1000°C.

In none of the laboratories was activity beyond normal T&I observed. However, the general competence in the T&I area was impressive.

#### POHANG IRON AND STEEL COMPANY (POSCO)

The Pohang Iron and Steel Company is an outstanding example of industrial success in the modern world. The company was formed about 1970, tapped its first iron in 1973. Since then growth has been steady and rapid. In February, 1981, the fourth blast furnace (world's 16th largest) commenced making iron; the present total capacity is 8.5 million tons a year. About 15,000 people are employed by the company. The company is now rolling steel to Japan, a remarkable achievement in this highly competitive market and during a time of decline for many of the world's steel companies.

POSCO uses modern L.D. converters to produce steel either by continuous casting or by pouring into ingot molds. Subsequently, slabs and blooms of the steel are processed by hot strip rolling, cold rolling, plate rolling, or in billetting on wire rod mills. The products include silicon steel sheets or strips, both grain-oriented and non-oriented. No further effort to produce alloyed steels is evident at this time.

The entire plant is computer controlled with respect to the use of power and fuels. All information processing systems are also computerized.

The technical research laboratory is modest but includes capability for x-ray stress analysis, electron micro-probe analysis, mechanical testing, and dilatometry. No current research work was shown; however, a considerable number of papers are being published by the company, all internally as near as could be determined. One author, D.W. Kim, presented reprints of a series of papers published by himself and coauthors in the POSCO *Technical Research Report*, 1 (1979) and 2 (1980). The titles with brief annotation are listed below:

*POSCO Technical Research Report , Volume 1, (1979)*

- "Study on the High Strength Steel Plates for API Five Pipe," D. W. Kim, (p.1). X70 grade can be produced by controlled rolling of Mo-Nb steel. The higher strength X80 and X100 steels require quenching and tempering. The addition of Ca, a rare earth metal, during steel making is necessary to avoid brittle fractures in high grade steel.
- "Effect of Controlled Rolling on the Mechanical Properties of Microalloyed Steels," D. W. Kim, (p. 47). The toughness, ductility, and strength of microalloyed steel containing Nb and V are optimum with rolling procedures which refine the grain structure. The optimum finishing temperature is 800°C.
- "Improvement of Pickling Rate of Hot Rolled Coil," D. W. Kim, (p. 79). Scale should be removed by pickling before cold rolling. The efficiency of pickling may be increased by control of roll finishing temperature, fast cooling of the coil after hot rolling, and by the use of rolling oil during hot rolling.
- "Review of the Manufacturing Process of Si Steel," D. W. Kim, (p. 109). The fundamentals of producing oriented and non-oriented silicon-iron soft magnetic material are reviewed.
- "Study on the Drawability of High Carbon Steel Wire Rod," D. W. Kim, (p. 177). Drawability is determined by microstructure, strength, and composition (alloying elements) of the steel. A fine lamellar pearlitic structure with optimum spacing of 420 angstroms is best.
- "Study on the Manufacture of High Strength Tempered Steels," D. W. Kim, (p. 205). The strength and toughness as influenced by heat treating variables and the addition of Ni were studied.
- "The Influence of S and C on the Magnetic Properties and Textures of Nonoriented Silicon Steels," D. W. Kim, (p. 243). Hysteresis loss increases with sulfur in the range of 0.01 to 0.025 percent.
- "Distribution of Nonmetallic Inclusions in the Slabs Cast by Continuous Cooling," D. W. Kim, (p. 257). Al-killed steel slabs cast continuously in a bow-type machine at POSCO show a concentration of  $\text{Al}_2\text{O}_3$  clusters 20-60 mm from the inner side. Such inclusions are irregular with respect to slab length.
- "Analyses of Surface Defects of Slabs and Ingots," D. W. Kim, (p. 277). Surface quality depends greatly on the temperature of the steel entering the mould, and on the teeming rate.
- "Comparisons of Korean and Japanese Refractories," D. W. Kim, (p. 311). A comparison is made on high alumina refractories, fire clay refractories, castable refractories, LD refractories, torpedo car refractories, and mouldable refractories. Korean refractories are of general lower quality because of greater porosity or problems with composition.
- "Comparisons of Magnesia Clinker between Domestic and Foreign Made," D. W. Kim, (p. 345). Magnesia clinkers from Japan and Korea were similar.

POSCO Technical Research Report, Volume 2, (1980)

- "Design of Coal Blending for Coke," D. W. Kim, (p. 1). Linear programming permits optimization of coal blending for coking.
- "Analysis of the Trajectory of the Thermal State of a Steel Ingot," D. W. Kim, (p. 9). A numerical procedure for analysis of the trajectory of the thermal state of the steel ingot agreed well with experiment.
- "Study on the Nonmetallic Oxide Catalysts for the Oxidation of Ammonia," D. W. Kim, (p. 67). Catalytic oxidation of ammonia with base metal oxides was studied. Specifically, catalytic activity of the system  $\text{Fe}_2\text{O}_3 - \text{Bi}_2\text{O}_3 - \text{Ce}_2\text{O}_3$  was studied, with a spinel carrier over the temperature range 420 to 920°C and at 1 atm pressure.

Oxidation of ammonia increased with temperature to 620°C. The highest oxidation coefficient was equal to that obtained with a platinum catalyst.
- "Investigation of Tempered Martensitic Steels for Pressure Vessels," D. W. Kim, (p. 119). Optimum heat treatments and the effects of Ni additions were evaluated for tempered martensitic Mn-Mo-V steels. The optimum tempering temperature was 650°C for high strength and good toughness. Increasing nickel contributed to temper embrittlement and a higher FATT.
- "Microstructures of Continuous Cooled High Carbon Steel Wire Rod," D. W. Kim, (p. 147). Fine lamellar pearlite in 0.64 percent carbon steel aids in drawability. In general, Nippon Steel Corporation rod is superior to the current POSCO rod with respect to drawability.
- "Relation Between Mechanical Properties and Microstructures of Weld Heat Affected Zone of High Strength Steel," D. W. Kim, (p. 205). The relations between the microstructure of the weld heat affected zone of high strength steels after submerged arc welding to mechanical properties, especially impact energy, were studied. The impact properties depend on austenitic grain size and on the transformation products, martensite, and upper bainite (high energy input during welding) or lower bainite (low energy input).

These papers are representative of the type and level of work being conducted within the research environment of POSCO. Obviously, the work is directed at improvements in current products through greater technical control. For this purpose, the work is good. The research experience gained will also doubtless lead to more diverse and higher risk research in the near future.

KANGWON INDUSTRIAL COMPANY, LTD.

Kangwon Industrial Company is physically adjacent to Pohang Iron and Steel Company, and primarily draws on this steel source to produce a variety of heavy industrial steel products. For example, an assortment of bars, angles, channels, I-beam, and rail products are made. Generally steel from POSCO is melted in an electric furnace and either continuously cast or cast into ingot molds, followed by rolling into a final cross section.

The company produces also an assortment of large carbon and low-alloy steel castings. Examples are rolls for rolling mills and crushers, grinding mills, compressors, and other heavy items for mining, ship building, and other heavy industries. A number of these

products are made under license or technical agreement with foreign companies. For example, rolls are made under license with Blaw-Knox Foundry and Mill Machinery Inc., (U.S.A.). A few defense items such as castings for tanks are produced. Quality appeared to be generally quite satisfactory.

There was considerable interest in the research which ONR and NRL are doing, but there was no indication that Kangwon Industrial Company is itself doing any basic research.

## FIRST ASIAN CONGRESS OF FLUID MECHANICS

S.N.B. Murthy

### INTRODUCTION

The First Asian Congress of Fluid Mechanics took place 8-13 December, 1980, in Bangalore, India.

Fluid dynamics is a major branch of physics and has a great appeal as a discipline for scientific endeavor as well as a basis for many technologies. Occasionally one hears of the near extinction of excitement in fluid dynamics, especially experimental fluid dynamics, but even the incompressible Newtonian flow past a cylinder at reasonably large Reynolds numbers presents extremely serious challenges both in phenomenology and in computational prediction. Technological demands on fluid mechanicians require computational schemes of great complexity and magnitude even when simple physical models are introduced. A major part of experimental fluid mechanics is also becoming concerned with the development of nonintrusive instrumentation and of data acquisition and processing. Flow visualization is becoming a very valuable tool and is attaining great sophistication both in marking the flow and in data display.

Every school of applied mathematics, applied physics, and engineering can be expected to have some interest in fluid dynamics. Fluid dynamics is a vast branch of physics. The inclusion of natural convection, compressibility, high temperature effects, multi-phase composition, flexible boundaries and coating, non-Newtonian behavior, and so on add a great variety of complexities, each of which provides many opportunities for specialization.

Research in fluid dynamics may follow traditional lines or may develop, as in the case of turbulence and rotation, along "fashionable" lines, in the words of Hans Liepmann. At the current time, it is possible to identify, for example, a group of researchers in turbulence with "commitment to the concept of coherent structure" (in the words of Don Coles, "Prospects for useful research on coherent structures in turbulent flow," an invited paper at the First Asian Congress of Fluid Dynamics, to be published in the *Journal of the Indian Academy of Sciences*, during 1981), and they have identified a formidable body of problems that need to be solved in turbulence on that basis. Similar fashionable lines can be identified in other branches of fluid dynamics-in fact, in all branches of science-based on the development of a major point of view.

Archival publications, therefore, have been felt insufficient, too slow, too formal, for adequate exposure and discussion of new ideas. National, regional, and international meetings are organized on this basis: to convert names into personalities, ideas into avenues of research, to facilitate the meeting of minds and to enlarge and to sharpen one's vision.

The First Asian Congress of Fluid Mechanics had all of these objectives, but in the particular context of the Asian practitioners of fluid mechanics getting together on Asian soil in their own neighborhood: as stated very clearly by the three prime members of the organizing committee, namely

Professor R. Narasimha, Indian Institute of Science, Bangalore, India,  
Professor C.P. Chou, University of Beijing, Beijing, China, and,  
Professor J. Sato, University of Tokyo, Tokyo, Japan.

The First Asian Congress succeeded very well in meeting this objective: most countries of Asia, even those with comparatively new and small institutions devoted to engineering, took the opportunity to assemble in Bangalore and to present their research most seriously and in perspective.

## ORGANIZATION

The Organizing International Committee and the Indian National Committee (Appendix I) worked over a period of nearly two years in organizing the Congress. A great effort had gone into establishing adequate contacts in various countries and in selecting papers of quality.

The Congress was hosted by the Indian Institute of Science (Dr. S. Dhawan, Director, who also holds the important positions of Secretary for the Department of Space, Government of India, and Chairman, Indian Space Commission), and the National Aeronautical Laboratory (Dr. S. R. Valluri, Director). Satish Dhawan has been a well-known name in fluid mechanics. The National Aeronautical Laboratory is the premier laboratory in India for aeronautical research (materials, propulsion, aerodynamics, and electronics) supported by a number of defense, space, and other industries, and with a variety of experimental facilities.

The Congress was held principally in the Faculty Hall of the Indian Institute of Science, with some simultaneous sessions in an adjacent Library Building, and with poster sessions in the vicinity. The Institute, now nearly seventy years old, has one of the most beautiful campuses in India. It has a number of departments for science and different branches of engineering and is largely a graduate-level institution.

The local organizing committee, headed by Dr. S. Yagnik (of the National Aeronautical Laboratory, and a fluid mechanician of repute in India) made excellent arrangements for the Congress. In every way the organization met the best standards of international meetings: timely sessions, adequate time for discussion, excellent lunches, three evening receptions, a buffet dinner, and a cultural evening with rose water and jasmine, and music and dance.

One of the notable features of the Congress was the availability of synoptic abstracts (generally 1,000 to 1,500 words long and with full addresses of the investigators) of nearly all of the papers presented at the Congress. The abstracts were bound in three volumes, one of them devoted to the poster sessions. The synoptic abstracts (with all of the reference and with figures of results where necessary) were adequate in most cases to appreciate the contributions. It was announced during the Congress that the contributed papers would be published in full, after appropriate review, in the *Indian Journal of Technology*, possibly throughout 1981. It was agreed on all sides that a bound volume of the complete proceedings would only have been a matter of prestige serving little purpose as a reference text.

## PARTICIPANTS

The Asian participants to the Congress came from twelve countries not including India. The participants, of course, were not identified by nationality at the Congress. The Congress was not widely publicized outside Asia, therefore the non-Asian participation generally indicated some connection with India. A listing of the participants is provided in Appendix II.

It is remarkable that only two or three of the scheduled talks were not presented out of a total of about 150 contributions. The attendance from Asian countries was impressive. Except for the highly specialized topics, the attendance in all technical sessions averaged about sixty-five. The poster sessions were effective, of course, only with enthusiastic speakers.

## TECHNICAL PROGRAM

The technical program was organized as follows:

- An inaugural lecture by S. Dhawan, who described researches in fluid mechanics and aerodynamics at the Indian Institute of Science from about 1950 to 1965. Researches by Ghatge, Tietjens, Krishana Swamy, Narasimha and Badri Narayanan, as well as of Dhawan himself, during that period are well-known in world literature. The painstaking construction of basic experimental devices, innovation of simple observation and measuring tools, the uncovering of fundamental facts without directly seeking them (for example, the connection between turbulent spot formation and transition reported by Dhawan and Narasimha in 1958) form a story that is the beginning of every center of research.

- Seventeen invited talks, some of them with an hour of time for a scholarly exposition.

- Technical paper presentations in 24 formal and five poster sessions devoted to the following subject areas. The numbers in parenthesis indicate the number of papers presented.

- turbulence(32),
- vortices (4),
- flow and sound (5),
- high speed flows (8),
- aerodynamics (4),
- convection (4),
- biofluid dynamics (6),
- multi-phase flows (10),
- non-Newtonian flows (4),
- geophysical flows (9),
- transitional flows (5),
- reacting flows (4),
- applications (20),
- computational fluid mechanics (10), and
- stability (7).

The organizers did not seem to have placed any special emphasis in the selection of papers on national representation. The contributions had been based on the quality of research. The organizers also said that no attempt had been made to restrict the subject areas. The number of papers chosen in any subject, however, may not be a reasonable indication of the relative magnitude of research effort in the area or of the extent of advances made. In the area of turbulence only one out of five contributions apparently had been selected for inclusion in the program. In the area of reacting flows, perhaps all of the papers received had been included.

There are many ways in which papers at such a Congress can be assessed and related to current research activity elsewhere in the world. The most direct way is to examine a

contribution in terms of the genesis of the problem, the approach adopted, the perceptiveness and insight, ingenuity in experimentation and analysis, and the depth and scope of the results obtained. Even then one may have to pay some attention to the research environment and the background "school of thinking" of the investigator. It is perhaps largely true that the researchers in most Asian countries, except China, India, and Japan, are still largely of the European (and may even be of the British) schools. In China, India, and Japan the situation is more complicated insofar as background is concerned and also, there is substantial indigenous activity; for example, postgraduate thesis research and the research in national laboratories connected with the aerospace, nuclear, and general chemical technologies. On the other hand, in many Asian countries there is only a beginning of indigenous technology, or somewhat-sporadic developments, and at that stage the competition between working in fashionable frontier areas and devoting oneself to innovative research tools for a well-chosen research problem can be severe. Some areas, even those such as two phase flow, biofluid mechanics, or geophysical, or environmental fluid dynamics, which may be considered as of universal interest with a variety of interesting challenges in experiment and analysis, may not have the appropriate appeal or support. Professor C. G. Caro (Imperial College, London) was discussing the recent researches of R. C. Schroter on flows in mammalian lungs by the study of camels subjected to various levels of dehydration; support for that kind of research in any country even with camels can only come sporadically or in the later stages of overall technical development.

One point to be made here is about the availability and knowledge of current literature. There is no doubt at all that the researchers are well acquainted with current literature, both archival journals and conference proceedings. A reasonably critical attitude is developing towards published literature and this obviously marks in many cases the beginning of indigenous activity. The references in the Congress papers were up to date, well documented, and carefully reviewed.

Given this knowledge of current work and some background to research in fluid mechanics, one can ask the plain question: How many of the 150 papers would one want to go back to? In a broad sweep, one may find about one in three papers is sound and about one in five merits careful study. This may involve excluding one or two subject areas altogether as being simply "repetitive" of well-established approaches or generally unproductive.

One can write a critique of selected contributions from such a point of view in various subject areas. On the other hand, it may also be of interest to review the contributed researches on a national basis. This is the approach adopted in the following. The review presented here is, thus, more in the nature of a visit to various countries and reestablishing the valuable friendships made at the Congress. The review, it is hoped will serve the same purpose for anyone intending relating his own interests to the developments in various Asian countries.

#### TECHNICAL REVIEW

The technical review is divided into several parts: West Asia, India, China, Japan, and South and Southeast Asia. In each case the numbers indicated in parenthesis refer to the institutions listed in Appendix II.

#### WEST ASIA

In West Asia, from the Kingdom of Saudi Arabia, two papers were presented: one, on the nature of unsteady boundary shear stress in an S-shaped fully developed channel flow

and, two, on a generalized surface renewal model for analyzing the wall region. The experimental studies reported on S-shaped channels were diagnostic (2). The surface renewal model (of L.C. Thomas of the University of Tennessee who had been visiting Riyadh) was being developed for application to heat transfer problems (1). The unsteady molecular transport of momentum and energy in the vicinity of the wall is sought to be related in this model to the statistics of the turbulent bursting process.

Of the two contributions from Kuwait, one related to detailed measurements of an incompressible turbulent boundary layer with heat transfer subjected to a strong adverse pressure gradient, the measurements carried out at the Technical University, Berlin. The other contribution related to measurements carried out on the wake of a cylinder in crossflow, the data reconsidered in the near wake region.

From Iraq, two papers were presented. One was in the nature of a diagnostic investigation on the interaction of acoustic disturbances (generated by the flow itself) on the local turbulence intensity in a two-dimensional air flow. The other paper dealt with the problem of vortex shedding of bluff obstacles, in this case rectangular prisms, with large depth in the streamwise direction. Wind tunnel measurements had been undertaken both without and with moderate blockage effects. The shedding frequency clearly depended upon the depth of the body, and three different regimes were identified depending upon the growth of the shear layer over the body. This research is expected to be continued.

Three papers were presented from Iran, one on natural convection boundary layers and the other two on two phase flow with heat transfer and phase change. The onset of transition in natural convection boundary layers was studied with gases and liquids with different relations between temperature and molecular viscosity (2). The fluid dynamics of large diameter gas-condensate pipelines subjected to hydrostatic forces is largely an open problem, even the general flow patterns being unclear (1). Heat transfer in counter-current two phase flow in closed-end vertical tubes is the subject of the third paper. The interphase shear stress determines the critical heat flux for a film of given thickness in a pipe of given diameter (3).

## INDIA

From the Indian Institute of Science in Bangalore, papers were contributed that illustrated long-range interest in the following areas:

- development of nonintrusive instrumentation,
- convection,
- turbo machinery flows,
- wind mill flows,
- geophysical and atmospheric flows, particularly the fluid dynamics of the monsoon,
- turbulence in complex flows,
- non-Newtonian fluid flow,
- transonic flows,
- fundamental physical fluid dynamics,
- transitory flows,
- computational fluid dynamics,
- reactive flows and associated computational problems.

Narasimha (of the Indian Institute of Science) reported on some unique and very interesting atmospheric boundary layer measurements (velocity and temperature, mean and

turbulence quantities) made during and immediately following the total solar eclipse of 1979 that passed through parts of India. This is an excellent example of an idea and a rare opportunity to investigate it. With some luck in having left the sensors and recorders operating for several hours after the eclipse, it appears that two distinct time scales could be uncovered in the cooling and recovery of warmth of the earth and its near atmosphere.

The behavior of the tropical monsoon, which is related to the structure of the intertropical convergence zone and its motion, is of crucial importance to life in India. The Meteorology Office in Delhi, the IITM at Pune, and the researchers at Bangalore are deeply involved in the understanding of the structure of the Indian monsoon.

Papers from the National Aeronautical Laboratory at Bangalore were related to the following areas:

- nonequilibrium in turbulent boundary layers,
- physical fluid dynamics,
- turbulent mixing between boundary layer fluids, and
- computational fluid dynamics.

A large research laboratory exists with Bharat Heavy Electricals, Ltd. That laboratory reported on some turbo-machinery flows. Close collaboration exists between the National Aeronautical Laboratory and the BHEL Laboratory.

There are five Indian Institutes of Technology (IIT), at Kharagpur, Bombay, Madras, Kanpur, and Delhi. These are the premier educational centers for engineering in India. Each of them has also a strong group in applied mathematics. The papers at the Congress, however, seemed to have come largely from the engineering departments. Nearly all of the papers, except those on computational techniques, had some experimental results. Some of the various topics covered in the papers were as follows:

- effect of swirl on flows,
- diffusers,
- turbo-machinery flows,
- forced convective heat transfer problems,
- computational fluid dynamics.

The next category of engineering educational institutions may be said to be the Regional Engineering Colleges. Contributions from these were generally in the same subject areas as the IIT's.

Finally, a number of contributions were reported from university institutions that were largely individual efforts. It appeared that there was a clear difference in the nature of problems studied in universities compared with those studied in the newer, obviously better-endowed IIT's and Regional Engineering Colleges. The university papers were more in the nature of contributions in applied mathematics.

Many institutions in India have excellent exchange and collaborative efforts with research institutions in the U.S.A., the British Commonwealth and many European countries. They also participate in many international research problems. The university-type institutions again seem to be keen on playing a greater role in these research programs. The Fluid Mechanics Institute at Bangalore University has made some advances in recent times.

## CHINA

Eight contributions were presented from China including two invited talks: one, on the theory of the decay of homogeneous, isotropic turbulence by P. Y. Chou and, two, on the application of stream function approach to transonic flow computations; for example, supercritical wings and cascades, by T. C. Lin of the Institute of Mechanics. The other six papers dealt with, one, an analysis of the formation of Karman vortex street (2); two, a model for ablation wedges based on boundary layer transition processes; three, a perturbation analysis for three-dimensional thin wings in unsteady supersonic flows (4); four, a kinetic model for nonequilibrium flows that are of interest in gas lasers; five, numerical-computation of wing-body-tail configurations in subsonic flow by the use of panel method; and six, a wind tunnel study on flow past cooling towers with simulated atmospheric boundary layer (1). In developing the model for ablation wedges, test results obtained with various ablating bodies in a hypersonic tunnel were shown (4). The kinetic model for nonequilibrium flows involved the introduction of a gain coefficient in the interval of molecular speed, related to the photo function. In principle, the model is completely general (4). Professor T. C. Lin apparently is in charge of a great part of research in fluid mechanics at the Institute of Mechanics.

While the total number of contributions was obviously small for a large country such as China with a variety of educational and research institutions, the papers gave, in perspective, an excellent sample of the researches in basic and applied fluid mechanics. The power of numerical-computational methods has clearly been recognized and considerable innovation is being developed to utilize available computational tools. Aeronautical, space, and generally energy-related technologies are clearly in the background in the formulation of applied problems.

## JAPAN

The number of visitors from Japan was the largest at the Congress with 22 contributions including five invited talks. The invited talks dealt with, one, mathematical modeling for prediction of turbulent shear flow (The University of Electro-Communications); two, visualization of the formation and structure of vortices (T. Matsui), which presented some of the most intriguing and beautiful features of vortices; three, numerical studies on the initiation of vascular lesion from a hydrodynamical point of view (Department of Physics, Keio University); four, three-dimensional aspects of boundary layer transition (I. Tani); and five, selected thermal and fluid mechanical problems for space flight (Institute of Space and Aeronautical Sciences.) The remaining papers were generally related to the same broad topics with considerable emphasis on the physics of fluid flow.

Two of the papers on turbulence dealt with experimental studies on establishing the relation between, (a) burst and the interface and, (b) the interface and wall pressure fluctuations in a boundary layer. More studies are to be continued (12). There was also a paper on the transitional and fully-developed turbulent boundary layer on an oscillating flat plate (4). Another contribution dealt with measurements in turbulent near wakes with pressure gradient and a simple model based on Reichardt's inductive theory (4).

In the area of vortical motion, an important paper dealt with mechanism of vortex shedding by a cone placed on a flat plate and a possible explanation for the formation of discrete clouds in the wake of isolated islands (5). Another paper was concerned with the interaction of two pairs of rectilinear vortices (an extension of the problem of interaction of a pair of ring vortices). Numerical calculations based on potential theory were shown to

be adequate to explain visual observations (of slip through) by the use of smoke-wire technique (11). Yet another paper dealt with sound generation due to the head-on collision of two high speed (subsonic) vortex rings: in the experiment the rings had been produced using a shock tube. The theory of vortex sound was based on the recognition of a flow scale and an acoustic wave propagation scale and the formulation of a general three-dimensional problem governing the inner eddy region, the outer acoustic region, and an intermediate connecting region. Viscous diffusion was shown to be important in the interaction (8).

Three papers were presented in the subject of high speed flows: one, a continuing investigation on analytical-numerical solution of the formation of a shock wave in the wave front of nonlinear waves (7); two, a method for obtaining shockless transonic flow past airfoils (12); and three, a method for determining the crossflow shock on a delta wing (7).

A paper on the lateral migration of a spherical particle in Poiseulle flow made use of the Green's function (of the Stokes equation) for a circular tube and provided a technique for establishing the migration direction. In another context of two phase flow, the transonic flow of a bubble-gas mixture was analyzed based on quasi-one dimensional flow and utilizing a nonlinear perturbation technique. The relative translational and radial motions (which are unstable) to some form of disturbances and give rise to a combination of two-stream instability and oscillation of bubble volume were analyzed in analogy to a turbulent plasma (16).

In the area of biofluid dynamics, a model experiment and some qualitative results were presented on the generalization of Korotkoff sounds in human brachial arteries. The tube collapsibility and transmural pressure were shown to be important parameters in determining the durable and impulsive sounds. This is continuing work (6).

Finally, a paper was presented on the numerical simulation of the break up of a capillary jet. The model took into account the free surface curvature at the nozzle exit and the associated forces. There was also reference to some earlier experimental work on the breakup of ink jets (14, 15).

#### SOUTH AND EAST ASIA

In South and East Asia the contribution from Sri Lanka dealt with experimental investigations on slow-running vertical axis wind rotors (the Savonius type rotors). The ratio of rotor height to rotor wake width was shown to have a significant influence on performance, and the diameter of an end plate, when included, has to take into account that ratio.

Two papers were presented from Thailand: one, the investigations conducted for a M.Sc. thesis on flow through porous media, wherein the square root of permeability was shown as one of the characteristic lengths of pore spaces and, two, the thermal diffusion in the sea front of Ao Phai due to the submerged discharge of cooling water from a proposed nuclear power plant near Bangkok. The interaction between tidal and discharged flows was analyzed utilizing an experimentally estimated "dilution rate" (for heat).

The three papers from Malaysia dealt with three different subjects: one, wave force analysis for submerged horizontal cylinders that is of interest in the design of submarine pipelines; two, a model for the thermal explosion that may occur upon contact of dissimilar liquids with certain temperature differences; and three, an experimental and analytical investigation of a dilute suspension of calcium carbonate particles stabilized by ionic

micromolecules. In utilizing the flow approach rather than the wave diffraction theory for the calculation of wave forces, it was shown that the inertial parameter may not be treated as a lumped parameter (1). The thermal explosion problem was the subject of a doctoral thesis at the University of California, Berkeley, and the author is continuing the development of a four-part interaction model (3). The pseudoplastic behavior of suspension is clearly related to the influence of the shear rate in the flow for a given concentration, since both the bringing together of the particles as well as the destruction of the "net-work" structure of agglomerations depend upon the shearing action (2).

From the University of Hong Kong, N. W. M. Ko reported on the extension of his earlier researches at Southampton related to jet noise suppressors. In particular, his paper dealt with the near field measurements of pressure fluctuations and the structural characteristics.

Five papers were contributed from Korea: two papers on natural convection, one paper on the onset of thermally induced instabilities, one on flows in T-branch pipes, and one on an eddy viscosity model for lightly loaded gas-solid suspension flows in pipes. The research on the problem of Rayleigh-Bernard instabilities, in which the base temperature is time-dependent and vertically nonlinear, was described as a continuing, long-range effort at Seoul National University. Experimental results are hard to come by in this area. The prediction of recirculating flows in T-branch pipes is based on the A. D. Gosman (1969) code generated at the Imperial College, London.

## CONCLUSION

The Congress could be compared to the Euromech Colloquia, the Commonwealth Scientific Meetings, the Australian Hydraulic Conference, and the Fluid Dynamics Meetings in Poland. The papers presented could probably be divided into three groups: one, contributions that were an extension of the initial inspiration of the researchers; two, contributions arising in the context of national technological and other developments and; three, the more relaxed, basic investigations along fashionable and traditional lines. Many Japanese contributions belonged to the third category. The Chinese and Indian contributions seemed to belong both to categories two and three. Some excellent investigations were reported from the smaller countries, even with comparatively new engineering schools. In general, the Asian and non-Asian contributions fitted into a natural pattern. Thus, Van Atta's paper (Van Atta from the University of California, San Diego was on a near-global sabbatical tour) on the measurement of the wall pressure field of a turbulent spot and Karamcheti's paper on discrete frequency sound generation in fluid flows (related to the structure of turbulence, flow instabilities and interactions with material surfaces) were of considerable interest in the context of Japanese, Indian, and Hong Kong contributions.

It was decided at a business meeting held towards the end of the Congress that a second congress is certainly something to look forward to in two or three years: Professor Chou of China, after consultations with appropriate authorities in China, extended an invitation for the next Congress to be held in China. Regional and special topic meetings were also discussed. Geophysical fluid mechanics, more particularly ocean fluid dynamics was mentioned. There was also a feeling that specialized topics in fluid mechanics such as two phase and biofluid mechanics may have received more emphasis. But these suggestions are bound to arise in any large gathering of fluid mechanicians.

## APPENDIX I

Members of the International Scientific Committee are:

- H. Sato (Tokyo, Japan) Chairman
- G. Ahmadi (Shiraz, Kingdom of Saudi Arabia)
- K. M. M. Alshamani (Baghdad, Iraq)
- P-y Chou (Beijing, China)
- A.K.M.F. Hussain (Houston, Texas, for Bangladesh)
- M.I.Khan (Lehore, Pakistan)
- C-o Lee (Seoul, Korea)
- K.O. Lim (Penang, Malaysia)
- A.M.M. Mayyasi (Kuwait)
- S. El-Sherbiny (Dahran, Iran)
- S. Sivasegaram (Paradeniya, Sri Lanka)
- S. Vongvisessomjai (Bangkok, Thailand)
- R. Narasimha (Bangalore, India) Secretary

Members of the National Organizing Committee are:

- S. Dhawan (Indian Institute of Science, Bangalore), Chairman
- A. Bhattacharyya (Indian Society of Theoretical and Applied Mechanics)
- P.K. Das (Indian Meteorological Department)
- S. Kar (Indian Institute of Technology, Bombay)
- M.G.K. Menon (Council of Scientific and Industrial Research)
- S.G. Ramachandra (Institution of Engineers)
- R. Ramanna (Defense Ministry)
- M.N. Venkatesan (Central Water Commission)
- S.R. Valluri (National Aeronautical Laboratory)
- K.S. Yajnik (National Aeronautical Laboratory)
- R. Mahindra (Hindustan Aircraft Ltd.)
- R. Narasimha (Indian Institute of Science) Secretary

## APPENDIX II

### ASIAN PARTICIPANTS

China

Beijing University, Beijing  
China University of Science and Technology  
CARDC, Mianyang  
Institute of Mechanics, Chinese Academy of Sciences, Beijing

Hong Kong

University of Hong Kong

India

Aligarh Muslim University  
Anudhra University, Waltair

Bangalore University  
Berhampur University  
Bharat Heavy Electricals, Ltd.  
Hindustan Aeronautics, Ltd.  
H.B.T.I., Kanpur  
Indian Institute of Science, Bangalore  
Indian Institute of Technology, Bombay  
Indian Institute of Technology, Kanpur  
Indian Institute of Technology, Khargpur  
Indian Institute of Technology, Madras  
Indian Institute of Technology, New Delhi  
I.I.T.M., Pune  
Indian Statistical Institute, Calcutta  
Meteorology Office, Delhi  
Motilal Nehru Regional Engineering College, Allahabad  
M.B.M. College of Engineering, Jodhpur  
University of Madras Post Graduate Center, Coimbatore  
National Aeronautical Laboratory, Bangalore  
University of Roorkee  
Regional Engineering College, Warangal  
Regional Engineering College, Tiruchirappalli  
S.V. Regional Engineering College, Surat  
Vikram Sarabhai Space Center, Trivandrum

#### Iran

Abadan Institute of Technology, Abadan  
University of Tehran, Tehran  
University of Work, Tehran

#### Japan

University of Chofu, Tokyo  
The University of Electro-Communications, Tokyo  
Hiroshima University, Hiroshima  
Hokkaido University, Sapporo  
Institute of Space and Aeronautical Sciences, Tokyo  
Keio University, Hiyoshi  
Kyoto University, Kyoto  
Kyushu University, Hakozaki, Fukuoka  
Maijo University, Nagoya  
Nagoya Institute of Technology, Nagoya  
Nagoya University, Nagoya  
National Aerospace Laboratory, Tokyo  
Ochanomiza University  
Riooh Company Ltd., Ota-Ru  
University of Tokyo  
University of Tsukuba, Ibaraki

#### Kingdom of Saudi Arabia

University of Petroleum and Minerals, Dahrان  
University of Riyadh, Riyadh

**Korea**

Korea Advanced Institute of Science, Seoul  
Pusan National University, Pusan  
Seoul National University, Seoul

**Kuwait**

Kuwait University

**Malaysia**

Jurutera Consultant (S.E.A.), Kuala Lumpur  
University Kebansaan Malaysia, Kuala Lumpur  
University of Malaya, Kuala Lumpur

**Pakistan**

College of Engineering, Lahore

**Sri Lanka**

Faculty of Engineering, Paradeniya

**Thailand**

Asian Institute of Technology, Bangkok

**OTHER PARTICIPANTS**

**Australia**

University of New Castle

**Canada**

University of Windsor  
University of British Columbia

**Egypt**

University of Cairo

**Federal Republic of Germany**

University of Karlsruhe  
Ruhr University, Bochum  
University of Stuttgart

**France**

Inst. de Mech. Statistique de la Turbulence, Marseilles

O.N.E.R.A.  
Universite du Poitiers

United Kingdom

Imperial College of Science and Technology  
University of Salford  
University College of Wales

United States

Boeing Commercial Airplane Company  
California Institute of Technology  
CHI, Lexington  
University of California, San Diego, LaJolla  
University of Houston  
University of Iowa  
Purdue University  
Shygart Associates, Sunnyvale  
Stanford University  
Wichita State University

## NUCLEAR MAGNETIC RESONANCE (NMR) IMAGING IN JAPAN

Allen N. Garroway

### INTRODUCTION

One peripheral reason for my trip to Japan in March 1981 was to visit colleagues with interest in NMR imaging. In 1971-1973 three groups had independently shown that images could be produced by nuclear magnetic resonance (NMR). Those principal researchers are Professor R. Damadian [State University New York, (SUNY), Brooklyn, U.S.A.], Professor P. C. Lauterbur [State University New York, (SUNY), Stony Brook, U.S.A.] and Dr. P. Mansfield (University of Nottingham, U.K.). Since then many other laboratories have contributed and the first commercial NMR scanners for head or whole body are now appearing.

### NMR IMAGING

The principle behind NMR imaging is quite simple. The magnetic resonance frequency of a nucleus is directly proportional to the magnetic field seen by the nucleus. In a uniform magnetic field of, say, 0.1 tesla (1 kG) the hydrogen nucleus resonates at 4.2 MHz. If a linear field gradient (perhaps 1 G/cm) is applied in addition to the static field, then the resonance condition will vary across the sample, e.g., nuclear spins on one side will resonate at a higher frequency than on the other side. The resulting NMR spectrum represents a projection of the nuclear spin density onto an axis defined by the direction of the field gradient. If the specimen is rotated, then a different projection results. The image of the nuclear spin density can then be reconstructed from this suite of projections by a computation similar to the one employed for x-ray computerized tomography (CT). A host of NMR imaging techniques have been developed; for example, in the above illustration, the direction of the gradient is best switched electronically rather than mechanically.

So far NMR imaging has been tailored almost exclusively to medical applications, although my particular interest is in the development of NMR imaging for nondestructive testing of polymeric systems. Excellent brain scans and some whole body cross-sectional scans of human patients have been demonstrated by a number of groups worldwide. Medical NMR imaging is generally discussed in the context of x-ray CT. NMR imaging does not involve ionizing radiation. Exposure is to a static magnetic field of about 0.1 tesla, a radio frequency field with an average power density much less than the ANSI recommendation of  $10 \text{ mw/cm}^2$  and a field gradient of about 1G/cm (which may be pulsed). Most evidence indicates that no harmful effects of such exposure should be encountered, but the safety aspect is still an open topic.

The NMR image is actually a composite of the nuclear spin density and the local longitudinal and transverse spin relaxation times T1 and T2, respectively. In the head the atomic density varies by about 5% and it is primarily this rather small variation which provides the image contrast mechanism in x-ray CT. In hydrogen NMR imaging, though the density variations in the body are small, the relaxation times vary over many orders of magnitude: e.g., the hydrogen in protein is quite immobile and has a very short T2, while much of the water within a cell moves quite freely and has a very long T2. Further, variations in the NMR relaxation times may have physiological significance. In 1971, Professor Damadian suggested that the hydrogen relaxation time T1 could be used to distinguish cancerous and noncancerous growths. Subsequent research fails to find a general unambiguous relation between the relaxation times in cancerous and noncancerous

tissues but does suggest that in certain instances relaxation times, or combinations of relaxation times, may be useful in assisting the identification of carcinoma.

## PROGRESS

Progress in NMR imaging will occur in two areas. Technically, one looks for increased resolution, faster scan times, and improved picture quality as the contrast mechanism is better exploited. More importantly, significant clinical experience must be gained with workable NMR scanners to determine which features of the NMR image are clinically significant. (In this respect, NMR imaging will come of age when it is no longer compared directly to x-ray CT, but rather stands on its own.)

Worldwide, about a dozen companies are building NMR scanners. Many of these have already competed vigorously in the x-ray CT market. To date, two commercial imagers have been installed and many more are expected within the next year.

## NMR IMAGING IN JAPAN

Four companies in Japan are developing scanners. They are: Toshiba, Hitachi, Sanyo, and Shimazu. All are at rather early stages in development of a scanner. In Japan, I visited Professor H. Yasuoka, a physicist at the Institute for Solid State Physics of Tokyo University. Professor Yasuoka collaborates with Toshiba on imaging, and one of his former students, Dr. H. Satoh, now works for Toshiba on the imaging project. I also met Dr. T. Inouye of Toshiba. In Professor Yasuoka's laboratory an NMR spectrometer, designed originally for studies of nuclear antiferromagnetism, has been converted to a small-scale imager. The magnet gap of 9 cm is quite adequate for small specimens: they have produced very attractive hydrogen NMR images of a lotus root and an okra. A reconstruction algorithm is used: at present, discrimination out of the projection plane is done by the restricted size of the rf coil, and they are about to implement a selective method to define the projection slice. They are purchasing an air coil electromagnet from Bruker (F.R.G.) for scaling up to whole body images. Professor Yasuoka is especially interested in the possible use of relaxation times to detect cancer. It is difficult to estimate the time required for this prototype to evolve into a viable commercial whole body system, but I would guess that two years of NMR work is required. Presumably, Toshiba's experience in computations for x-ray CT can be applied almost directly.

Dr. Inouye told me that Japan has the highest number of x-ray CT scanners on a per capita basis, so Japan is a natural market for NMR scanners. Quite a lot of money is involved, as whole body NMR scanners will cost on the order of \$0.5 - \$1.0 million.

I was unable to visit any of the other industrial laboratories. Only Professor Yasuoka's group has published NMR pictures and I was told elsewhere that other industrial groups are not as far along. Other researchers who have contributed to NMR imaging are Dr. Z. Abe at Musashi Institute of Technology (Tokyo) and Dr. H. Kamei of the Electrotechnical Laboratory in Ibaraki.

Purchase of a U.S.-made NMR scanner, manufactured by the FONAR Corporation, is planned for this fall, according to an article in the *Yomiuri Daily* of 4 April 1981. A few years ago, Professor Damadian left SUNY at Brooklyn to found FONAR. A "Society to Study the NMR Scanner" has been established in Japan and consists of 120 researchers and physicians. Dr. S. Takahashi, Chief of the Cancer Research Center in Aichi Prefecture, will serve as coordinator. The location of the proposed scanner was not specified in the article.

Installation of such a scanner and evaluation by the study group will certainly aid in identifying the clinical benefits of NMR scanners. Then too, import of such an expensive U.S.-made scanner into Japan will provide more impetus for Japanese development of a scanner industry. A stiff international competition is expected in the next few years.

#### Appendix I

##### Mailing Addresses of Principal Investigators Mentioned in this Article

Name	Address
- Professor R. Damadian	Department of Medicine and Biophysics State University New York Downstate Medical Center Kings County Hospital Brooklyn, NY 11203
- Professor P. C. Lauterbur	Department of Chemistry State University New York Stony Brook, NY 11794
- Dr. P. Mansfield	University of Nottingham United Kingdom
- Professor H. Yasuoka	Institute for Solid State Physics University of Tokyo 1-22, Roppongi 7-chome Minato-ku, Tokyo 106
- Dr. H. Satoh	Toshiba Corporation 1, Toshiba-cho, Saiwai-ku Kawasaki, Kanagawa 210
- Dr. T. Inouye	Toshiba Corporation 1, Toshiba-cho, Saiwai-ku Kawasaki, Kanagawa 210
- Dr. Z. Abe	Musashi Institute of Technology (Tokyo) 28-1, Tamazutsumi 1-chome Setagaya-ku, Tokyo 158
- Dr. H. Kamei	Electrotechnical Laboratory Agency of Industrial Science and Technology, MITI 1-1-4, Sakura-mura, Umezono Niihari-gun, Ibaraki 305
- Dr. S. Takahashi	Chief, Cancer Research Institute 65, Tsurumai-cho, Showa-ku Nagoya, Aichi 466

## 1980 ANNUAL MEETING OF THE INSTITUTE OF ELECTROSTATICS JAPAN

Leon H. Fisher

### INTRODUCTION

The fourth annual meeting of the Institute of Electrostatics Japan was held at the Tokyo Metropolitan Industrial Technology Center, Tokyo, on October 8 and 9, 1980. All of the sessions were in Japanese. However, I was able to get something out of the meeting for a number of reasons. Although copies of the papers were distributed whose text was in Japanese, the titles and abstracts were in English. Professor M. Hara of the Department of Electrical Engineering of Kyushu University sat next to me some of the time and acted as interpreter. Furthermore, I had already visited a number of times the laboratory of Professor S. Masuda at the University of Tokyo whose work was reported at the meeting. Subsequent to the meeting, I visited the laboratories of Professor M. Akazaki at Kyushu University and Professor K. Asano at Yamagata University; papers from both of these laboratories were given at the meeting. Moreover, Professor Asano had, by the time of my visit to his laboratory, prepared a review of the meeting for publication in the *Journal of Electrostatics* (Elsevier), and we spent an afternoon discussing his review. (Incidentally, Masuda is Regional Editor for Asia of the *Journal of Electrostatics*). It was also a help to be able to call on Masuda, the president of the Institute, for assistance. I attended the meeting at Masuda's invitation, was asked to be present at the executive luncheon session of the Institute held during the meeting, and was asked to give a short talk at the banquet. I was the only non-Japanese present at the meeting.

### ACTIVITIES OF THE INSTITUTE OF ELECTROSTATICS JAPAN

A brief description of the activities of the Institute of Electrostatics Japan was given in this Bulletin, 5(1), 34 (1980). Some further information is now presented.

The Institute at present has four committees. Each of these committees holds a meeting every two months and these meetings are open to all Institute members for free discussion. Each committee is empowered to establish a subcommittee for an important topic for a certain limited period (1-2 years) with limited financial support (100,000 yen per year). However, meetings of the subcommittees are closed and are limited to experts to enable detailed discussion and study. Although each subcommittee must issue a report on its findings to all members of the Institute, there is at present only one subcommittee operating. The present committee activity consists of:

- Committee on Fundamentals of Electrostatic Phenomena (includes field calculations and discharge phenomena),
- Committee on Electrostatic Precipitation,  
Subcommittee on Measurement of Dust Resistivity (purpose is to arrive at a common reasonable procedure to measure dust resistivity because, at present, different values are obtained by different measuring methods),
- Committee on Electrostatic Processing (includes all the application of electrostatics other than electrostatic precipitation, such as electrostatic coating, powder coating, electrostatic printing and imaging, etc.,

- Committee on Electrostatic Safety and Measurement (includes electrostatically induced ignition phenomena, safety precautions, system approach of safety engineering, and all kinds of electrostatic measurements).

Another important activity of the Institute is the publication in May, 1981, in Japanese, of a *Handbook of Electrostatics* (OHM Sha Book Co.). This handbook includes basic phenomena and safety procedures with respect to electrostatics. The Institute is also planning to issue a safety manual, and to institute training courses for operators using electrostatic equipment, and to issue certification of their ability to operate such equipment safely.

The Institute also gives awards (including cash) under the following categories:

- Award for Prominent Merit (awarded for an outstanding scientific contribution to the progress of electrostatic science or engineering, and also for an outstanding service in promoting activity in this field in the Institute),
- Award for Prominent Paper (only for work in the field of electrostatics),
- Award for Prominent Technical Development,
- Award for Prominent Book (only in the field of electrostatics),
- Presidential Award (a very special award recently established for an important invention, important improvement, or clever idea which however was not submitted in a paper because of lack of educational background; designed to encourage technical activities and inventive ideas of self-educated inventors or workers).

At the 1980 Annual Meeting, prizes were awarded for:

- a new method of rapping electrostatic precipitators,
- a new electrostatic precipitator for collecting small aerosol particles,
- a device for elimination of electrostatic charging of clothes,
- development of an electrostatic filter to remove welding fumes, and
- the use of electrets to keep material adhering to surfaces (the awardee gave me a spectacular demonstration).

The Institute seems to have strong industrial support. For purposes of reference, the address of the Institute is given:

c/o Business Center for Academic Societies Japan  
2-4-16, Yayoi, Bunkyo-ku, Tokyo 113, Japan

#### THE MEETING

Four invited and 57 contributed papers were presented at the meeting. The invited papers were presented in plenary sessions, but the contributed papers were presented in two simultaneous sessions. We now discuss the papers.

#### INVITED PAPERS

"Old and New Matters," J. Takagi, Waseda University, Emeritus. This paper gave

some history of electrostatics going back to Thales of Miletus and to Gennai Hiraga (1726-1773), the first Japanese to experiment with electricity and who invented an electric generator for medical use. Singularities in the electric field surrounding sharp insulators were discussed with special reference to work of the author.

"Formation of Lichtenberg Figures Using the Japanese Ancient Art Form of Suminagashi," Y. Sekido, Nagoya University, Emeritus. Sumi means charcoal and nagashi means flowing, hence suminagashi means flowing charcoal or flowing Chinese ink. If a paint brush is wetted with Chinese ink and is touched to a water surface, the ink spreads on the surface in a variety of forms. By placing a cloth on the surface of water, the pattern can be transferred to the cloth. Recently, the practice of photographing the pattern has become popular. This is the art of suminagashi which has been practiced in Japan since ancient times. In olden times, suminagashi was practiced by members of the noble classes, especially women. Modern Japanese artists still practice suminagashi. The spreading process of the ink on the water was studied by Terada around the turn of the century. In the present paper, the ancient art of suminagashi was extended to include the effect of touching a metal point charged to a very high potential to the surface of ink on water, a grounded metal plate being placed underneath the water. The resulting pattern is a novel type of Lichtenberg figure. In 1777, G. C. Lichtenberg found that spectacular figures are formed on the surfaces of dielectrics if high voltage pulses are applied to sharp points in contact with the dielectrics (the other sides of the dielectrics being in contact with grounded flat conductors). The present paper included a demonstration (rather a disappointing one, probably due to the primitive demonstration facilities available) of patterns produced using both positive and negative points. (The study of Lichtenberg figures has been very popular in Japan for many years, especially at Nagoya University. U. Shinohara spent a great deal of time and effort studying Lichtenberg figures at Nagoya University until he became president of that institution. He in turn was a student of Y. Toriyama, now in his late eighties, who has spent his life studying Lichtenberg figures. Toriyama, now an Emeritus Professor of Electrical Engineering at the Musashi Institute of Technology, Japan's MIT, in Tokyo still works on Lichtenberg figures and published a book in 1961 entitled *Dust Figures of Surface Discharges and Their Application*, Kinokuniya Press).

"Problems in the Application of Electrostatics to Printing," Y. Hozaka, Toshiba Co., Ltd. This paper discussed problems encountered in electrostatic imaging in which unstable corona destroys the paper or causes poor images. An electrode configuration and electrical circuit to obtain stable corona was described. The nozzle configuration and biasing voltages for improving the response time of an electrically driven ink jet printer was described. Droplet formation at 60 kHz was achieved.

"Application of Electrostatics to Facsimile Printers," M. Anzai, Hitachi Co., Ltd. It was pointed out that the process by which latent images formed electrostatically are transferred, using liquid developers, is not understood. The use of charges thermoplastics for electrostatic imaging was proposed.

#### CONTRIBUTED PAPERS

The contributed papers were divided into four groups:

- electrostatic phenomena,
- electrostatic precipitation,
- electrostatic processes, and
- safety systems.

The title and authors and a brief description of some of the contributed papers will now be presented. In some cases the titles (as given in English by the author/s) have been changed slightly for clarity, and in some cases the order of authors has been changed so that the same institution does not have to be listed twice in the same paper.

## ELECTROSTATIC PHENOMENA

"Charge Stability of Corona Charged Elongated Polytetrafluoroethylene Films," T. Takamatsu, E. Ogawa, and E. Fukada, The Institute of Physical and Chemical Research, Wako-shi, Saitama 351. Polytetrafluoroethylene films were elongated axially up to six times the original length and annealed. The films were then electrified by corona charging and thermally stimulated depolarization current was measured. The depolarization current increases with increasing elongation and increasing annealing temperature. Charge traps are created by elongation and stabilized by annealing.

"Effects of Injected Charges on Tree Initiation in Polyethylene," N. Yoshimura, M. Nishida, and F. Noto, Faculty of Mining, Akita University, and S. Fujita, Hachinohe Institute of Technology. Measurements were made of the potential of a negative point necessary to produce trees (surface breakdown, Lichtenberg figures) as a function of pulse width and temperature (20°C to 80°C).

"Upper and Lower Bounds for Effective Dielectric Constant of Composite Materials," M. Nakamura and K. Haruna, Department of Electronics, Tamagawa University, Machida, Tokyo 194. This is a calculational paper using the finite element method.

"Thermally Stimulated Currents in Polymers," K. Shindo, Department of Physics, Faculty of Education, Shiga University, Otsu, 520. Experimental results obtained for thermally stimulated depolarization currents agree with those obtained for thermally stimulated polarization currents.

"Effects of Additives on the Thermally Stimulated Current in Polyethylene," N. Fukushi, Central Research Laboratory, Showa Denko K.K. Thermally stimulated currents in polyethylene with various additives show spectra characteristic of each additive. The magnitude of the peaks in polyethylene without additives increase if additives contain methylene chains.

"Thermally Stimulated Depolarization Current of Polysubstituted Benzenes (II). C. Kitazawa, Iryo Gijutsu Tandai, Shinshu University. Thermally stimulated depolarization currents were measured with polycrystalline tetrachloro-o-xylene under different polarizing conditions, and a single peak was observed in the range from -170° to -125°C, and this was at -140°C. The activation energy for the molecular rotation was evaluated.

"Analysis of Sodium Ions in Thermal SiO<sub>2</sub> Films Using a Corona Charging Method," S. Iwamatsu, Fujimi Plant, Suwa Seikosha Co., Ltd., Fujimi. Experimental results to estimate and reduce the sodium ion densities in thermal SiO<sub>2</sub> films by an electrostatic method were presented.

"Effects of Moisture on Electrification of Polymer Powders," H. Matsuura, M. Takeuchi, and H. Nagasaka, Department of Electrical Engineering, Ibaraki University. This paper describes the effects of moisture on the corona charging and frictional electrification of polymer powders. The corona charging properties of the powders were studied by measuring the surface potential decay of powdered layers. Frictional electrification of powders was measured by the blow-off method. In the case of corona

charging, the plot of the logarithm of the surface potential  $\psi$ , the square root of time shows a linear characteristic except for an initial decay. This decay rate increases with increasing moisture content of the powders. However, the initial surface potential does not vary with moisture content. In the case of frictional electrification, the amount of charged generated increases with a decrease in relative humidity except in extremely dry atmospheres where the charging was less than in a slightly humid atmosphere.

"Preliminary Investigation of Electrostatic Pesticide Spraying," K. Asano and S. Jittoku, Faculty of Engineering, Yamagata University, Yonezawa. This study was undertaken to devise a system which would reduce the amount of pesticide reaching the ground and maximize the amount on a plant. A two-fluid atomizer was used and a grounded metal sheet covered by paper on both sides was placed at a fixed distance from the nozzle. The deposition rate at the back side of the sample was determined as a function of the applied voltage, the configuration of the charging electrode, etc. The deposition rate on the back of the paper varied with these parameters, but not independently.

"Charging Characteristics of an Ink Jet and Its Applications," K. Asano and H. Suzuki, Faculty of Engineering, Yamagata University, Yonezawa. A previously published theory by the authors on ink jet charging has been extended to varying conductivities. Practical problems such as distortions of the printed letters in an actual ink jet printer were discussed.

"Charging Characteristics of an Ink Jet and Its Applications," K. Asano and H. Suzuki, Faculty of Engineering, Yamagata University, Yonezawa. A previously published theory by the authors on ink jet charging has been extended to varying conductivities. Practical problems such as distortions of the printed letters in an actual ink jet printer were discussed.

I saw demonstrations of the three experiments mentioned above during my visit to Yonezawa.

"Onset Mechanism of Corona Discharge on Water Drops," M. Hara, T. Kaneko, T. Yamashita, Faculty of Engineering, Kyushu University, Fukuoka, and C. H. Park and M. Akazaki, Graduate School of Engineering Sciences, Kyushu University, Fukuoka. This paper is part of a continuing study. The authors tried to distinguish between the pure corona discharge from a water drop and the corona induced by electrostatic instability of the drop by varying the pressure. Pure corona should depend on pressure and the corona formed by electrostatic instability of the drop should be independent of pressure. The study was carried out for drops varying in radius from 0.5 to 3.5 mm. If the radius is large, then the surface disruption mode prevails. This study is important for understanding the effects of water drops on transmission lines.

"Corona Current Characteristics of Water Drops Suspended from a High Voltage Conductor," T. Tanibe, M. Hano, T. Adachi, Faculty of Engineering, Yamaguchi University, and M. Kawasaki, Nishinippon Institute of Technology. As far as I can determine, this paper is mistitled as no corona current characteristics were presented. Rather a study was made of the time duration of hissing and crackling corona when water drops were allowed to fall on a cylindrical conductor at high potential. Both polarities were studied. There are certain field strengths for which the hissing and crackling last the longest time. It is hoped that this study will help understand the vibration of high voltage lines which occurs in rainy weather.

"Behavior of a Droplet on Organic Insulating Materials Under DC Stress," M. Nishida, N. Yoshimura, and F. Noto, Department of Electrical Engineering, Akita University. Droplets (presumably of water) were placed on four dielectrics which were placed between two parallel electrodes. The four dielectrics were chosen so that the contact angles were different. The droplet radius was about 3.0 mm and the electrode separation was 2 cm. A dc voltage with a rise time of 250 V/sec was applied. Above a certain dc voltage, the droplet undergoes certain changes described by the authors as expansion "toward the electrodes" and subsequent "deformation." A discharge finally forms through the deformed droplet. The voltage to start the deformation of the drop as well as the voltage to start a discharge is larger the smaller the contact angle. The voltage to start a discharge increases with decreasing radius of the droplet.

"Effects of a Protrusion on a Smooth Conductor on the Distribution of Electric Field and Ion Current Density at Ground Level in a DC Field," N. Hayashi, M. Akazaki, Graduate School of Engineering Sciences, Kyushu University, Fukuoka, and K. Shiotsuki and M. Hara, Faculty of Engineering, Kyushu University, Fukuoka. The experimental results showed that for a two dimensional protrusion on a smooth wire, the magnitudes of the electric field and current on the ground become larger and their distribution wider than that without the protrusion. A knife edge of 2 mm height was soldered onto a smooth conductor of 1 cm diameter. This study may apply to protrusions on conductors such as insects and rain drops on transmission lines, and the results may help to determine the right of way of transmission lines. (The right of way of transmission lines is now a very important subject in Japan because of the high density of population. If one requires fields and currents to be confined to a certain area on the ground, then such effects as discussed in this paper are of very great practical importance). (I saw this experiment at Fukuoka).

"Influence of Wind on Fields and Current Densities at Ground Level beneath Smooth Conductors with DC High Voltage," M. Hara, K. Shiotsuki, Faculty of Engineering, Kyushu University, Fukuoka, and N. Hayashi and M. Akazaki, Graduate School of Engineering Sciences, Kyushu University, Kyushu, Fukuoka. Using the same apparatus as was used in the previous paper, and with the addition of a uniform air flow, electric fields and current densities at the ground were measured for high voltage dc corona. A voltage supply capable of giving 150 Kv both positive and negative is available for these studies. The experiments are being performed in a large room in the open air and blowers at one side of the apparatus cause the wind. There is no influence of wind on the corona current per unit length of wire. The profiles of the electric field (measured with field meters) and current density (the measuring plane is divided up into a number of insulated collectors) change with wind speed and the magnitude of the applied voltage. The position representing the maximum values of electric field and current density shift down stream and their maximum values decrease as compared with those in still air. The results indicate that the ratio of wind velocity to drift velocity of ions due to the electric field is one of the basic parameters to evaluate the influence of wind. (I saw this experimental set up when I was at Kyushu University.) The results of this work will be described by Hara at the IEEE meeting to be held in Portland, Oregon during the summer of 1981.

"An Electrostatic Voltmeter with Strain Gauges," M. Hattori, Y. Saito, and K. Asano, Faculty of Engineering, Yamagata University, Yonezawa. The voltmeter consists of two electrodes, one of which is fixed and the other is of small mass and movable, and is supported by two massive brass beams. Between the movable electrode and the supporting beams, four strain gauges are inserted to form a Wheatstone bridge in order to compensate for ambient temperature changes. Both ac and dc voltages were found to give a linear dependence of the signal on the applied voltage.

"Demonstration of Electrostatic Phenomena," B. C. Kuang, N. Murasaki, K. Fujibayashi, and M. Matsui, Faculty of Technology, Tokyo University of Agriculture and Technology. An educational apparatus consisting of a cell containing kerosene, short filaments of a synthetic fiber, and electrodes to visualize lines of electric field was demonstrated.

"Computational Simulation of Two-dimensional E. H. D. Convection," M. Suzuki and Y. Sawada, Research Institute of Electrical Communication, Tohoku University.

"Calculation of Electrostatic Potential in a Floating Tank with an Electrode on the Axis," H. Mitera, Faculty of Engineering, Niigata University, and H. Matsumura, Chubu Electric Power Co. Calculations were made of the potential of a spherical conducting probe placed on the axis of a cylindrical tank filled with oil having a uniform charge density. Calculations were made for tanks 40 cm in diameter and 30 cm high and 40 cm in diameter and 40 cm high for probes of 2 and 4 cm diameter. The maximum field strength of the electrode occurs at a distance of three times the electrode radius from the center of the tank.

"Measurement of Surface Potential Distribution in a Cylindrical Tank," M. Kawasaki, Y. Matsubara, Fire Research Institute, 14-1 Nakbara 3-chome, Mitaka, Tokyo; T. Hagiwara, K. Kinoshita, National Research Institute of Police Science; and T. Kodama, Research Institute of Industrial Safety. The surface potential of a 8.2 m diameter cylindrical tank partially filled with charged oil was measured by using field meters placed on a grid 20 cm above the liquid surface. It was hoped that these measurements could be compared with those expected for uniform charge distribution, but it was found that the potential distribution is influenced by motion of oil in the tank.

"A Direct Measurement of Electrostatic Potential on the Surface of Oil in a Big Oil Tank Using a New Telemetering Field-Meter System (II)," M. Matsui, N. Murasaki, and K. Fujibayashi, Faculty of Technology, Tokyo University of Agriculture and Technology. The signal from a probe is telemetered from a probe assembly floating on the surface of the oil at 78 MHz. In a second method, the potential of the probe is converted to an optical pulse and transmitted by an optical fiber cable. The probe involves the use of  $^{241}\text{Am}$ .

"Electrostatic Voltage Sensor Using Surface Acoustic Waves," R. Inaba, Y. Kasahara, and K. Wasa, Materials Research Laboratory, Matsushita Electric Industrial Co., Ltd. Electric fields can be measured by the elastic strain they induce in piezoelectric materials. Such strains were measured by a surface acoustic wave technique. A delay line type surface wave oscillator was constructed using piezoelectric materials, and the frequency change of the surface wave oscillator was measured when an electric field was applied. Piezoelectric materials used included piezoelectric ceramic "PCM",  $\text{LiNbO}_3$  and quartz. With the piezoelectric ceramic, a frequency change of 400 Hz was obtained for a voltage of 40 volts.

"Influence of Frequency on Corona Onset Voltage in Liquid Nitrogen," Y. Takahashi, Faculty of Technology, Tokyo University of Agriculture and Technology, and T. Sakakibara, Faculty of Science and Engineering, Chuo University. Corona onset and extinction voltages were measured with point-to-plane electrodes in boiling nitrogen at atmospheric pressure. The onset voltage is independent of frequency between 50 and 500 Hz. The peak values of the onset voltage in an ac field lie between the onset for positive and negative corona in dc fields. The extinction voltage is almost as high as the corresponding onset voltage.

## ELECTROSTATIC PRECIPITATION

"Moving Belt Type Electrostatic Precipitator for Control of Diesel Engine Particulates," S. Masuda and J. D. Moon, Department of Electrical Engineering, University of Tokyo. Usually a troublesome problem in electrostatic precipitation is the formation of back corona generally ascribed to high resistivity of the particles being precipitated. However, diesel engine particles have extremely low resistivity. Electrostatic precipitators trying to clean such exhausts suffer from the difficulties of insulation of the discharge electrode system due to carbon contamination of the insulators, and also from an excessive reentrainment of collected soot. Both of these difficulties are due to the low resistivity of the particles to be collected. Furthermore, diesel deposits are fluffy. For these reasons, a moving belt type electrostatic precipitator was developed in which the insulating electrodes are outside of the gas collecting system. The collecting electrode is a thin flexible stainless steel belt supported by rollers giving belt velocities up to 2 m/min. The discharge electrodes are fixed to a rigid frame which is supported by two rods at both ends. These rods extend through the gas outlet openings and are insulated outside so that carbon contamination of the insulators is avoided. The dirty gas is introduced through two inlet ports at the center of the belt, and flows towards both sides through the collection field. The wire (0.1 mm diameter stainless steel) to belt spacing was 13 cm, and 18 kV (6 kV/cm) was applied between the wires and the belt to provide an average current density as high as 1.75 mA/m<sup>2</sup> under soot loaded conditions at 40°C. The fluffy and porous conducting layer of soot is pressed between the rollers and the belt to form a dense flake which is scraped off mechanically. The pressing reduces the volume of the soot by a factor of about 20. The collections performance for an average gas velocity of up to 1.5 m/s was found to be about 93%. The actual tests were carried out with a soot generator burning city gas giving a median diameter of 1.0 micrometer; this is about three times larger than that obtained from diesel engines.

"Application of Boxer-Charger in Electrostatic Precipitators," S. Masuda, H. Nakatani, and H. Kawahara, Department of Electrical Engineering, University of Tokyo. The principle of the boxer-charger was described in this Bulletin, 5, (1), 48 (1980). The present paper describes a new form of boxer-charger in which each ion source consists of a double-helical electrode unit and uses a nanosecond high voltage pulse for excitation to produce plasma. (I saw this system operate and spectacular filamentary discharges appear between the adjacent turns of the two helices.) This configuration is an improvement over the planar boxer-charger because the charging field intensity can be increased substantially, and edge effects as well as difficulty in construction and installation are reduced. The use of this boxer-charger in front of a collecting field increases the dust migration velocity by a factor of 2.4 under severe back discharge conditions.

"On-Line Dust Monitor Using Boxer-Charger," S. Masuda and K. Akutsu, Department of Electrical Engineering, University of Tokyo. A new instrument was described based on electrostatics for continuous monitoring of dust mass-loading which is not affected by surface properties of dust as is the case in optical and triboelectric instruments. Dust particles are charged by a boxer-charger to Pauthenier's limit and led to a suction-type Faraday-cage for detection of charge. Experimental results obtained with six different dust samples showed that the current to the Faraday cage is proportional to the dust mass-loading, provided the flow rate of carrier gas and the size distribution is kept constant.

"Measurement of Positive and Negative Ionic Current Densities Under Back Discharge Conditions," S. Masuda and Y. Nonogaki, Department of Electrical Engineering, University of Tokyo. The severity of back discharge in electrostatic precipitators can be

measured quantitatively by the ratio of the positive ion to negative ion current density in the volume excluding the immediate region around the discharge electrode, the severity increasing with increasing value of this ratio. A novel type of bipolar probe was developed to measure positive and negative currents independently. The probe is either spherical or cylindrical, and is in three parts, one facing the discharge electrode, the other facing the collecting electrode, and the third a neutral electrode in between. Measurements were made with such probes using a point-to-plane electrode corona with several kinds of dust. It was found that the positive ion current density can amount to as high as 30% of the negative ion current density under severe back discharge conditions.

"Behaviour and Mutual Interference of Glow-mode Back Discharge Points," S. Masuda and K. Tatsumi, Department of Electrical Engineering, University of Tokyo. The glow-mode of back discharge was studied using mica plates with pinholes backed by a conductor as a model for the dust layer. An increase in the number of pinholes per unit area results in a decrease in current per pinhole, but the total current rises. At low voltages, only the inner surfaces of the pinholes glow. With increasing voltage, strong luminosity appears inside each pinhole, and with further increase in voltage, filamentary discharges emanate from each glow.

"Effects of Ripples and Polarity and Dust Resistivity on Corona Discharges in Electrostatic Precipitators," A. Iijima, Origin Electric Co., Ltd., and S. Masuda, Department of Electrical Engineering, University of Tokyo. The effects of ripples on back discharge was studied using a duct-type model electrostatic precipitator with the back discharge being produced by covering the surface of the collecting electrode with a paper towel. The resistivity of the towel could be varied between  $1.5 \times 10^8$  and  $9 \times 10^{11}$  ohm cm by changing the relative humidity of the air. For both polarities, the corona current is independent of ripple ratio and the sparkover voltage decreases with increasing resistivity although the decrease is greatest for the negative wire. For this reason, operation would be better with a positive wire under back corona conditions.

"Charging of Aerosols by Corona," T. Sato, Department of Electrical Engineering, Hokkaido Institute of Technology.

Particles of known diameter were charged by passing them through a corona discharge and then into a uniform discharge free electric field. The drift velocity of the particles due to the electric field was determined by a laser doppler velocimeter making corrections for wind velocity. The charge on the particles was determined from Stokes' law and was found to vary with charging time and corona ion density and to increase slightly with increasing corona voltage, eventually reaching a saturation value.

"Dependence of Collection Efficiency on Size of Precipitator Duct with a Wet Scrubber," (Title drastically revised by L.H.F.), A. Kaga, Faculty of Technology, Osaka University. DOP mist of mean diameter  $1 \mu\text{m}$  was enlarged to  $2 \mu\text{m}$  diameter by steam condensation and then introduced into an experimental electrostatic precipitator whose duct size was varied. The collection efficiency was found to be roughly independent of duct size from 4 cm to 40 cm, in accord with theory.

"Electrification Characteristics of Sphere in Tri-Electrode Charger," M. Ogihara and A. Shibuya, IHI Corp. Ltd., (Ishikawajima Harima Industries), I. Hattori, Technological University of Nagaoka, and Y. Tabata, Industrial Safety Institute, Ministry of Labor. A steel ball was either suspended in or allowed to fall through a corona formed by a tri-electrode charger. In this way the current and electric field in the charging region could be varied independently. It was found that the applied voltage is dominant in

determining the charge on the ball suspended from a string and that the current is dominant for the dropping ball case.

"Numerical Analysis of the Electric Field in a Non-Concentric Cylindrical Electrostatic Precipitator," M. Hano, T. Adachi, Faculty of Engineering, Yamaguchi University, and M. Kawasaki, Nishinippon Institute of Technology. Since one method to prevent vibration of a wire electrode in an electrostatic precipitator is to place the wire slightly off center, the authors decided to calculate the field of a noncoaxial wire and cylinder corona arrangement. The method involved successive approximations. The results were tested by dropping a spherical metal ball through such a corona discharge. The electric field strengths agreed to within 10% with the measured values where the displacement of the discharge electrode from the center of the cylinder was 1 cm and the applied voltage was 25 kV.

"Corona Induced Vibration of Discharge Wire in an Electrostatic Precipitator," M. Kawasaki, Nishinippon Instite of Technology, and T. Adachi, Faculty of Engineering, Yamaguchi University. This is a calculational paper in which a simple vibration model with one degree of freedom is assumed and some data from a bench scale duct type precipitator is inserted. The results show that the vibration frequency of the wire agrees with the calculations to within 3%, the vibration force is not more than  $22 \times 10^{-2}$  N, the vibration energy per cycle is less than  $2 \times 10^{-3}$  J, and the ratio of vibration energy to electric energy is less than 0.15%.

"Use of Charged Droplets to Deposit Submicron Particles in Electrostatic Precipitators," (Title drastically revised by L.H.F.), M. Hara, S. Sumiyoshitani, Y. An-no, Faculty of Engineering, Kyushu University; S. Fujimoto and M. Akazaki, Graduate School of Engineering Sciences, Kyushu University, Fukuoka. This work is an attempt to develop a new method of adding water to charged dust particles to enlarge the diameter so that electrostatic precipitation of submicron particles is possible. Charged (usually positively charged) water droplets from an insulated metal needle are introduced into a stream of gas containing nonspherical dust particles which have been charged (opposite in polarity to the water drops) by allowing the dust to be carried by air through a corona discharge. The collection efficiency for the irregularly shaped dust in an electrostatic precipitator was measured as a function of charging voltage and the results were compared with the theoretical values obtained for spherical particles. The collision efficiency between charged droplet and particle was also discussed.

"Motion of Submicrometer Charged Particles Inside an Electrostatic Precipitator," S. Masuda, K. Akutsu, and S. Nakata, Department of Electrical Engineering, University of Tokyo. The motion of submicrometer charged DOP particles was investigated inside a horizontal duct model electrostatic precipitator using a laser doppler velocimeter. The component of the velocity toward the collecting electrode was found to be independent of particle size near the collection electrode. However, this component increases with increasing particle size in regions far from the collecting electrode.

"Behavior of Charged Powder in Electric Fields (Part 2)," Y. Tonoya and Y. Nakamura, Tokyo Metropolitan Industrial Technical Institute. The charging of powders by corona, friction, and induction were compared for a number of powders. It is found that corona charging is ten times as efficient as frictional charging.

"Electrostatic Charging of Two Metal Spheres in a Corona Discharge," K. Sakabayashi, Faculty of Science and Technology, Chuo University; Y. Tabata, Industrial Safety Institute, Ministry of Labor; and M. Ogihara, IHI Corp., Ltd. The theoretical

formula for charging of a spherical particle given by Pauthenier is for an isolated body. However, the present paper is concerned with the charging problem when many particles are charged simultaneously and one particle may obstruct the other. For this purpose, two 1 cm metal spheres were placed in a corona discharge so that one sphere was closer to the discharge than the other and the second was behind the first. The experiment showed that the charge on the back sphere is less than that of the front one because of the blocking of ion current by the front sphere. The corona configuration was wire to cylinder.

"Measurement of Corona Field at Grounded Electrode," K. Fujibayashi, K. Nishizawa, M. Matsui, and M. Murasaki, Faculty of Technology, Tokyo University of Agriculture and Technology. This paper describes the automatic recording of the electric field at the collecting electrode using the biassed probe developed by Tassicker.

"Electrostatic Precipitation of Submicron Particles," M. Furuya and T. Takahashi, Fuji Electric Corporate Research and Development Ltd. Smoke consisting of tar mist of mean radius 0.53  $\mu\text{m}$  were precipitated using a two-stage electrostatic precipitator. Theoretical calculations of precipitation efficiencies using Pauthenier's and Deutsch's equations are in fair agreement with the experimental results.

"Electrostatic Precipitator Using Ultrasonics," T. Nakane and K. Seya, College of Industrial Technology, Nihon University. A vibrating plate 28 x 7.5 x 0.1 cm was placed between the sources of aerosol smoke particles and a duct-type electrostatic precipitator. The plate was driven at 20 kHz and voltages of up to 15 kV were applied to the precipitator. The collection efficiency is greater in the presence of the ultrasonic source especially at low voltages. The improvement increases with aerosol concentration. However, the maximum efficiency of the precipitator was at most about 75%.

"Control of Current in an Electrostatic Precipitator by Application of an Intermittent AC Voltage Superimposed on the DC Voltage," (Title drastically revised by L.H.F.), M. Yamaguchi, T. Miyashita, Hitachi Research Laboratory, Hitachi Ltd., and T. Ooura, A. Akasaka, and M. Hayatsu, Hitachi Plant Engineering and Construction Co., Ltd. This method is proposed as an alternative to pulsing to obtain improved precipitator efficiency. The method was found to improve collection efficiency over the dc voltage method for high resistivity dust ( $10^{11}\text{ohm m}$ ) in both model and full scale precipitators.

## ELECTROSTATIC PROCESSES

"Retardation of Vaporization by Electric Fields," Y. Asakawa, Asakawa Laboratory. Experiments were described that showed it is possible to retard vaporization of water, to prevent mold in matter, and to preserve food by the application of electric fields.

"Electrostatic Separation of Compost," K. Tabei and T. Takahashi, Fuji Electric Corporation Research and Development, Ltd. An artificial sample compost consisting of 95% pure compost and 5% glass bits was subjected to cleaning with an electrostatic precipitator. It was possible to obtain compost of up to 99.5% purity. The most suitable moisture content was found to be 20%.

"Construction of Electret Motors," K. Kudo, Faculty of Engineering, Meiji University. An electret motor was described whose stator consists of two polarized electret mylar films and whose rotor consists of two aluminum electrodes to which two point electrodes supply and remove charge. The motor requires a minimum of about 3.5 kV and is capable of operating at a minimum power of 1 mW at about 300 rpm with a current of 0.2  $\mu\text{A}$ .

"Electrostatic Powder Classification by Travelling-Field-Type Charger," K. Fujibayashi, M. Matsui, and N. Murasaki, Faculty of Technology, Tokyo University of Agriculture and Technology. Spherical particles of  $10\mu m$  diameter were charged by means of a travelling-field type charger based on the boxer-charger device. The particles were then introduced into a uniform electric field travelling parallel to the electrodes. The particles were collected and it was found that the larger particles were collected on the part of the electrode closest to the charger (because such particles have a larger charge and hence a higher mobility).

"Control of Fish by Electric Stimulation," T. Oda, S. Masuda, and T. Fujita, Faculty of Engineering, University of Tokyo. The possibility of a sea farm by using electric stimulation-control of fish was examined experimentally. The response of goldfish and carp to electric field stimulation was observed by a TV monitor for dc, sinusoidal, and pulsed fields. The stopping power of the electric field for fish depends on the value of the field and the pulse width. A pulsed field with 0.1-1.0 ms pulse-width showed the best performance in relation to power consumption. The frequency dependence of the stopping power is very small. The conclusion is that there is a good possibility for an electric net in fresh water, but that the power consumption in sea water would be 10-100 times as large.

"An Electrostatic Method of Handling Pellets," S. Masuda and M. Washizu, Faculty of Engineering, University of Tokyo. This work is designed to study methods of charging ice pellets and guiding and storing these charged pellets by electric quadrupole fields to desired locations. The studies are motivated by the need to have methods available for the guiding of deuterium-tritium ice pellets so that they can be irradiated by laser radiation for producing thermonuclear reactions. The particles are charged with the boxer-charger, and pellets of a given charge to mass ratio is selected by a quadrupole field and stored until injection into the laser plasma generation region. Preliminary results were presented. It is expected that this system will be developed in about two years.

"Contact Electrification of Various Metal Oxides," and "Contact Electrification of Inorganic Phosphors," T. Oguchi, Research and Development Center, Toshiba Corporation and M. Tamatani, Consumer Products Engineering Laboratory, Toshiba Corporation. In the first of these papers, the electrification on oxide powders of 30 metal oxide powders when they came in contact with beads of each of three metals (Al, Fe and Pb) was measured. The test powder and metal beads were uniformly mixed and then the powder was blown away and the charge on the beads was measured. When the oxides are arranged according to the amount of charge obtained from contact with any one of the three metals, the order among the oxides is essentially the same as those obtained from the other two metals. The amount of charge varies from a large positive value in  $MgO$  to a large negative value in  $V_2O_5$ . In the second paper, similar studies were carried out for twelve inorganic phosphors.

#### SAFETY SYSTEMS

"Electric Conduction Phenomena in Silicone Liquid Using a Step Voltage Method with Polarity Reversal," I. Umetsu and K. Asano, Faculty of Engineering, Yamagata University. On reversal of polarity, the current shows a secondary peak which is interpreted as due to the migration of ions.

"Direct Discharging Method in Charged Oil Tank (II)," and "On the Discharging Effects by a Mesh Type Wire Net in Charged Oil," K. Tottori and M. Fujii, Faculty of Electrical Engineering, Fukui Institute of Technology. In the first paper, stainless steel nets of 100 or 200 mesh are inserted into oil at the entrance to oil tanks and grounded, thus tending to neutralize the charge of the streaming oil current. The oil tank studied had a

diameter of 40 cm and a height of 40 cm, and the velocity of the oil into the tank was reduced by a diffuser to about 10 cm/s. The results showed that this discharging method is effective with efficiencies ranging from 62.6% to 98.8% depending on the mesh sizes and arrangements of filters used as well as on the diameter and length of the input pipes.

"Charging Tendency of Aliphatic Alcohols (I)," S. Watanabe and M. Ito, Aichi Institute of Technology, and A. Ohashi, Faculty of Engineering, Nagoya University. Measurements of many liquids including methyl alcohol and ethyl alcohol were made in a stainless steel pipe of 0.2 mm diameter. The charging tendency was found to depend on many factors including the molecular parachor, the molecular weight and viscosity.

"Effect of Kind of Liquid and Material of Pipe on Electrification of Liquid Flow in Pipes," T. Kodama and Y. Tabata, Research Institute of Industrial Safety, Ministry of Labour. The electrification of hexane, benzene, toluene, xylene, and kerosene flowing in various vertical pipes made of stainless steel, copper, aluminum, and polyvinyl chloride were measured. The inner diameter of the pipes was 4 mm and the length was 1.6 m and flow velocities from 1.25 to 1.43 m/s were studied. By measuring streaming currents for various lengths, it was found that the currents increase with pipe length almost in agreement with the exponential build up theory. The results do not depend on the conductivity of the liquids.

"Information on Design of a Relaxation Pipe," N. Kitamura and M. Ueda, Faculty of Engineering, Nagoya University. This paper investigated the effectiveness of a relaxation pipe in reducing electric charge in petroleum in a transmission line. This paper is an extension of previous work in which parameters were given which gave a collection efficiency of over 80%. This paper discusses the influence of viscosity and other factors on the discharging efficiency.

"An Experiment on Streaming Electrification in the Connected Tank-Car Systems, Using Medium Sized Models," H. Yoshida, Japan Oil Transportation Co., Ltd.; S. Ichimura, Fuji Heavy Industries Ltd.; and M. Ueda and A. Ohashi, Faculty of Technology, Nagoya University. The authors have developed the connected tankcar system for unloading oil from trains by having oil movable between each tank through flexible rubber hose. In this way the contents of each tank can be loaded and unloaded continuously from the end of the train. This speeds up loading and unloading but may give rise to electrical hazards. The authors constructed 1/6 and 1/3 size models to investigate this matter. They conclude that the maximum flow speed can be as high as 4.5 m/s with a 20 cm diameter pipe.

## **U.S.-JAPAN SEMINAR: MEASUREMENT AND CONTROL OF PARTICULATES GENERATED FROM HUMAN ACTIVITIES**

Leon H. Fisher

### **INTRODUCTION**

A U.S.-Japan Seminar, Measurement and Control of Particulates Generated from Human Activities, was held November 11-13, 1980 at the Kyoto International Conference Hall, Kyoto, Japan.

U.S.-Japan seminars are meetings on scientific and engineering subjects and are held either in the U.S. or in Japan. Such seminars are part of the U.S.-Japan Cooperative Science program and are administered jointly by the Division of International Programs of the U.S. National Science Foundation and the Japan Society for the Promotion of Science (an agency of the Government of Japan).

Each U.S.-Japan seminar has two organizers, one American and one Japanese. Attendance is limited and is by invitation only. Although the bulk of attendees are from Japan and the U.S., as many as six delegates from other countries (third countries) may also be invited.

The organizers of the present Seminar were Professor Senichi Masuda, Department of Electrical Engineering, University of Tokyo, and Professor Melvin W. First, Department of Environmental Health Sciences, Harvard School of Public Health. The present meeting was the first one held on this subject under the auspices of the U.S.-Japan Seminar format.

There were 43 "regular" participants at the seminar, nine from the U.S., 30 from Japan, and four from third countries. Of the nine participants from the U.S., four came from industry, three from government, and two from universities. Of the 30 participants from Japan, 27 came from universities, two from industry and one from government. Fourteen Japanese universities were represented. Two of the third country representatives were from universities, one from a government research institute and the other from a government industrial institute. In addition, there were 27 "special participants" from Japanese industry. A list of all participants, including affiliations and addresses will be found in Appendix I. Fields of specialization are indicated for regular attendees.

### **PRE- AND POST-SEMINAR ACTIVITIES**

The Seminar opened on Tuesday morning, November 11, but was preceded by an extensive visit of Professor Iinoya's laboratory in the Department of Chemical Engineering of Kyoto University on Monday afternoon, November 10. The formal part of the Seminar ended Thursday afternoon, but a number of the non-Japanese participants visited the Nagoya Works of the Nippon Steel Corporation on Friday, November 15, the Masuda laboratory at the University of Tokyo on Saturday morning, November 16, and the Isogo Thermal Power Plant of the Electric Power Development Company, just outside of Tokyo on Saturday afternoon. I participated in all the field trips except for the one to the Isogo Thermal Plant and reports of the tours I attended are given in Appendices II, III, and IV.

### **GENERAL COMMENTS ON THE FIELDS COVERED BY THE SEMINAR**

The formation and handling of aerosols is an interdisciplinary activity. It requires the

attention of mechanical, chemical, and electrical engineers as well as chemists, physicists, and workers in the fields of public health and medicine. The study of aerosols is very complicated and requires a mixture of theory and experiment and empirical procedures which are not completely understood. The field has become more important with the advent of the oil crisis. Coal will have to replace oil in many situations with the aggravation of the fly ash problem arising from the increased use of coal. The push for higher fuel efficiency for small passenger cars is leading to an increasing use of diesel engines with the emission of very fine soot which is difficult to collect.

Work in the field of aerosols in Australia, Denmark, Italy, West Germany, Japan and the U.S. was reported at the Seminar. One might have hoped for an extensive comparison of the relative advantages of mechanical filtration and electrostatic precipitation. However, some devices using a combination of electric and mechanical effects were discussed. The difficult problem of collecting the fine conducting soot particles emitted from diesel engines received much attention.

#### THE SEMINAR PROGRAM

Presentations were designated as being in one of the following classifications:

- Review Talks (20 minutes),
- Topical Reports (almost all were 20 minutes long), and
- Comments and Discussion (5 to 20 minutes).

The program consisted of 12 Review Talks, 12 Topical Reports and 19 Comments and Discussion. There were no parallel sessions.

The presentations were organized into six sessions under the following heading:

- Measurement of Particles,
- Electrostatic Precipitation,
- Mechanical Filtration,
- Enhancement of Collection,
- Advanced Technologies and Sciences, and
- Diesel Particulates and Human Effects.

Titles, authors and summaries of papers are now presented. In some cases, comments made on papers are included. At the end of each session, summaries of the papers were given by one or both of the cochairmen of the session, and some of these summaries are included.

#### MEASUREMENT OF PARTICLES

"Measurement of Particulate Air Pollutants," (in Japan), K. Takahashi, Institute of Atomic Energy, Kyoto University. (Review Talk). A review was given of the methods usually employed in Japan for the measurement of particulate air pollutants with diameters less than 10  $\mu\text{m}$ . The low volume air sampler (~20 liter/min) provided with a horizontal elutriator is recommended as the standard sampler for ambient aerosols. Other methods commonly used include a high volume air sampler (1.5-2.0  $\text{m}^3/\text{min}$  sampling rate), filter sampling (takes a long time and does not give continuous readings), tape air samplers in which particles are deposited on a tape filter and scattered or attenuated light is measured (this method is not recommended because of poor linearity with mass concentration), and light scattering methods by the aerosols without deposition (this method has problems with

linearity at large mass concentration and gives results depending on the relative humidity and the kind of aerosol). Performance details were also given of a piezoelectric microbalance dust meter in which particles are charged by corona and then electrostatically deposited on the sensor, a beta-ray attenuation dust meter in which the particles are first deposited either by filtration or impaction on the measuring surface and the deposited mass is estimated from beta-ray attenuation, and a number of cascade impactors. Performance of instruments for measuring very fine particles, both in number and size, by condensation nuclei counters (CNC) was discussed.

"Measurement of Submicrometer Particles by *in situ* Techniques," K. T. Whitby and D. Y. H. Pui, Department of Mechanical Engineering, University of Minnesota. (Review Talk). This paper covered all of the significant *in situ* and some of the more important collection techniques for sizing and measuring the concentration of particles with diameters less than 2  $\mu\text{m}$ . Currently, more methods are available for ambient measurements than for source measurements. The ideal system of source measurement *in situ*, without extraction or collection, has not been realized except in a limited number of specialized applications. Because no single instrument is capable of accurate and reproducible measurement of particles over more than about one decade of particle size, several instruments are usually required to cover the entire fine particle size range from 2  $\mu\text{m}$  diameter down to 0.002  $\mu\text{m}$ , the smallest particles of concern. The size of liquid aerosols depend strongly on temperature. In practical field sampling systems, losses in sampling lines, bag systems, and diluters often limit the useful size range of an instrument or system. Particle size for irregularly shaped particles will depend on the physical principles involved in the measurement. Inertial, optical, electrical, and diffusional techniques were discussed. These techniques are used for particles in order of descending size. The frontier in particle measurement has gone from inventing instruments to developing systems for data reduction. One needs a space time trajectory of particles since the particles change with ambient conditions, sometimes reversibly (such as addition and subtraction of water) and sometimes irreversibly. The sampling of aerosols is a concern; few atmospheric sampling techniques are independent of the wind velocity. John Brockman has evaluated the sampling efficiency for the Aitken nuclei counter and has succeeded in measuring smaller particle sizes with it more than any one else has. Lu of the Lawrence Berkeley Laboratory has developed a sampling device which gives results independent of wind direction and velocity. A portable sampling device developed by GCA was discussed which is suitable for use in mines. Another new development is the microorifice impactor which consists of a plate with 10,000 50  $\mu\text{m}$  holes. The penetration decreases with increasing particle size and can sample high velocity flows. Another new development is the use of two laser beams to measure fringes to give a laser doppler measurement which gives particle sizes down to 0.5  $\mu\text{m}$ , with possible extension down to 0.2 or 0.3  $\mu\text{m}$ . (Lasers have not yet made much of an impact in the particle measurement field.)

"Dust Sampling for Particle Mass-Concentration Measurement," H. Masuda and H. Yoshida, Department of Chemical Engineering, Hiroshima University, and K. Iinoya, Department of Chemical Engineering, Kyoto University. (Topical Report). Problems related to dust sampling for particle mass-concentration measurements were reviewed based on results obtained in the authors laboratory during the last few years. Problems discussed included: the anisokinetic sampling error (isokinetic sampling is sampling at the same velocity as the gas velocity), sampling in stationary air, classification performance of virtual impactors, dust concentration measurements at extremely low sampling velocity, and electrostatic effects on isokinetic sampling.

"Comparison of Laboratory and Field Derived  $K_2$  values for Dust Collected on Fabric Filters," R. Dennis and J. A. Dirgo, GCA/Technology Division, GCA Corporation. (Topical

Report).  $K_2$ , the specific resistance coefficient for a dust layer, is defined as the ratio of the pressure drop across a dust layer to the product of filtration velocity and the thickness or areal density of the dust deposit. Values of  $K_2$  are necessary for the designing of large fabric filters. Fabric filtration is a large industry in both Japan and the U.S. Opportunities for direct determination of  $K_2$  based on routine field measurements are very limited because almost all fabric filter systems consist of many compartments operated in parallel and cleaned sequentially on a continuous or intermittent basis. With continuous cleaning, the fabric loadings, and consequently the filtration velocities, always differ, not only from compartment to compartment, but also from area to area on the surface of each bag. Theoretical values of  $K_2$  were obtained from the Happel modification of the Kozeny-Carman equation whereas experimental values were obtained on single panel or single bag systems (except in one case). Comparisons between measured and calculated  $K_2$  values for fly ash, talc dust, and granite dust show that the predicted values are consistently greater, by about a factor of three, than the measured values. Inaccurate porosity values are considered to be a major cause of the high  $K_2$  estimates. Whether the laboratory  $K_2$  values are applicable to full scale installations is not known.

"Sampling and Size Distribution Measurements of Submicron Aerosols," W. Stöber, Fraunhofer-Institute of Toxicology and Aerosol Research, Münster, (Comments and Discussion). Recent improvements of the spiral duct aerosol centrifuge facilitating the continuous use of the instrument as a quasi-on-line aerodynamic particle size spectrometer were discussed. The instrument is designed to measure mass distribution of nonvolatile aerosols in the size range from 0.05 to 5  $\mu\text{m}$ . The apparatus consists of a newly designed spiral duct rotor equipped with sensitive quartz detectors for *in situ* weighing of the deposited aerosol particles. Dr. First pointed out that the current design of centrifuges limits the sampling rate to 2 liters/minute. There is a possibility that this may be extended up to 5 or 6 liters/minute, but this is still low compared to the high velocity cascade impactor. S. Masuda asked if there is any theoretical basis to the shape of the spiral pattern. He stated that a recently completed theoretical study at the University of New Mexico gives a theory of flow which is independent of the shape of the spirals. The final design involved a semicircle and then an Archimedes spiral. However, the flow must not be turbulent. A model was built at the Los Alamos Scientific Laboratory.

"Development of a New Continuous CNC/Generation of Ultra Fine Aerosol Particles," Y. Kousaka, K. Okuyama, and T. Niida, Department of Chemical Engineering, Osaka Prefecture University. (Comments and Discussion). (CNC stands for Condensation Nuclei Counter). Ten different kinds of ultra fine aerosol particle generators were constructed. The best one involves evaporating the material of which the aerosol is to be formed by passing hot nitrogen gas over it and then quenching the material by passing it through a tube immersed in liquid nitrogen. The aerosols formed included  $\text{ZnCl}_2$ ,  $\text{NaCl}$  and DOP. The furnace temperature heating the gas was as high as 800°C for  $\text{NaCl}$  and as low as 155° C for DOP. The particles were subjected to a size distribution and number concentration measurement with a differential mobility analyzer using Hoppel's method. The newly developed continuous CNC was then used for the detection of aerosol particles after the differential mobility analyzer. The principle of the CNC is very similar to that of fog formation in the atmosphere caused by mixing warm saturated air with colder saturated air.

"Electrical Measurement of Submicrometer Dust Size Distribution with Mobility Analyzer," K. Fujibayashi, Department of Electrical Engineering, Tokyo University of Agriculture and Technology. (Comments and Discussion). Dust size can be estimated from the measurement of its mobility in an electric field provided it has a well-defined electric charge. A "rotary" charger designed on the same principle of the Boxer Charger invented

by Masuda was used to charge the particles. An ac quadrupole electric field was formed by four semicylindrical electrodes. Intermittent corona discharge in the semicylindrical electrodes supply ions through holes drilled in the walls of the semicylindrical electrodes. The aerosol flowing along the axis of symmetry is charged by ions moving to the axis. The sample aerosol was supplied from a fumigator in which a mosquito repellent incense was burned on glass wool and dust-free air streamed through the bed. Mobility was measured by a parallel disk analyzer.

"Shape Characterization of Particulates by Fourier Analysis," K. Gotoh, Department of Chemistry, Faculty of Fishery Engineering, Hokkaido University. (Comments and Discussion). This is a mathematical paper attempting to characterize particle shape characteristics. The vector distance from the center of gravity of a plane projection of the particle is expressed as a Fourier series  $A + \sum C_n \cos(n\theta + \phi_n)$ . Since A and  $C_n$  are rotationally invariant, they characterize the shape of the particle.  $C_n$  becomes inversely proportional to n at around  $n = 10$ , and hence the macroscopic shape of the particle can be characterized by the value of  $C_{10}/A$ . Values of  $C_{10}/A$  were given for 45 dusts. (It was not clear to me how these values were obtained.) Questions were raised by participants relating to the fact that the above method gives only the geometrical features of the particles whereas other quantities such as the aerodynamic equivalent diameter of the particles are important.

The papers in the first session were summarized by Dr. First, the cochairman of the session. A summary of his remarks follows. There is a tendency of the Japanese to cite Japanese work and for U.S. scientists to cite U.S. work. We are obsessed with particle size and the mathematical characterization of particle size is indeed important. We have been apprised of the advances made in measuring the size of particles in the finest part of the size spectrum. The measurement of aerosols at their source is complicated by the large concentration and wide distribution of particle size, but this question is being "mopped" up. Good aerosol problems never die. They get reinvestigated. Wall losses in cascade impactors were understood in 1950. We are still obsessed with sampling errors and isokinetic losses. The errors in measurement are due to the change in size and nature of the particles during measurement. An accuracy of  $\pm 30$  or perhaps  $\pm 50$  percent would be all that one can expect even in the best of circumstances and, as a matter of fact, a factor of two was mentioned this morning. Why is a single value for size given when a single number does not define what we are interested in? Why don't we subject our data to statistical analysis? What are the error bands?

#### ELECTROSTATIC PRECIPITATION

"Collection of Fine Particles of High Resistivity in Electrostatic Precipitators," W. B. Smith and G. B. Nichols, Southern Research Institute. (Review Talk). The present methods used for collecting high resistivity particles in electrostatic precipitators all make operating costs higher than the cost of collecting low resistivity particles. These methods include making the precipitators very large, using hot-side precipitators (although back corona problems have appeared even with hot-side precipitators), using additives, and using wet electrostatic precipitators (the collection efficiency of wet electrostatic precipitators is independent of the resistivity of particles). The problem with the hot-side precipitator may be involved in the time dependence of the dust resistivity. As current passes, alkali atoms in the dust may be depleted. Perhaps the procedure can be reversed. However, at the present operators are facing shutdown problems. The use of chemical conditioning agents is increasing. This seems to reduce the resistivity of the dust layer, increase the adhesivity, and reduce reentrainment. Chemical conditioners have some disadvantages in that they are hazardous and may be emitted into the atmosphere and that they are

expensive. However, of all the above methods, chemical conditioning is the least expensive. New electrification methods in electrostatic precipitation and novel designs now under development to avoid the increase in cost were discussed. These methods include, (1) superimposing pulses of very high voltage and short duration on the primary wave form, (2) the development of two-stage electrostatic precipitators, one stage for charging and the other for collecting and, (3) the development of novel precharging systems.

"Back Discharge Phenomena and Quantitative Identification of Its Severity," S. Masuda, Y. Nonogaki and T. Oda, Department of Electrical Engineering, University of Tokyo. (Review Talk). The overall severity of a back discharge can be identified by the actual charge on a particle divided by the maximum ideal charge it could have, by the ratio of the actual electric field to the field which would exist without back corona, and by the ratio of the drift velocity as determined from Pauthenier's equation under back corona conditions to the drift velocity determined from the same equation in the absence of back corona. However, the present paper describes the measurement of positive and negative ion current densities with a bipolar ionic current probe having three electrodes which seems to give more fundamental parameters with which to characterize back corona severity. The operation of the probe is described briefly in the report in this issue of the *Bulletin* on "1980 Annual Meeting of the Institute of Electrostatics Japan."

"Fugitive Dust Control by Charged Spray Scrubbers," S. Calvert and S. C. Yung, Air Pollution Technology, Inc. (Topical Report). Present methods used to contain fugitive emissions are ineffective and costly. A novel system, SCAT (Spray, Charging, and Trapping Scrubber), was described. It is a controlled disposal scrubber system for controlling industrial process fugitive emissions. It uses air curtain(s) and/or air push jet(s) to contain, divert, and convey fugitive particles into a fine particle scrubber. The SCAT system uses water sprays (which may be charged) for removing particles entrained in the gas stream. Some of the important features of SCAT are:

- minimum use of solid boundaries enabling access to the source,
- unobtrusiveness,
- portability,
- trapping and removal of particles rather than depositing them at the source site.

The present paper presents results on charged spray scrubber performance. It was found that spray scrubbing efficiency for fine particles is significantly improved by electrostatic charging of the spray, and even more by charging the particles as well. The use of small drops and larger charges on the drops promises to give better efficiencies than have been measured to date. Mathematical modelling of charged spray scrubbing has not yet yielded a method for predicting the magnitude of the improvement caused by spray charging.

"Present Status of Flue Gas Clean-Up Technologies for Coal Fired Boilers in Japan," Y. Nakabayashi, Electric Power Development Co., Ltd. (EPDC). (Topical Report). (EPDC produces seven percent of the electric power in Japan. It is 70 percent supported by the Japanese government and 30 percent by the private Japanese power companies. EPDC sells all of its power directly to private utilities.) At the present time, 3.7 percent of Japan's electric power comes from coal-fired plants. By 1995, it is planned that this percentage will increase by a factor of about four with an annual coal consumption of 80 million tons. Domestic coal production is expected to remain at the present level (approximately 20 million tons a year). The coal-fired plants which will be constructed will use coal imported from the Rim Pacific nations. Coal-fired power stations to be built in Japan must be designed to use various types of imported coal, not just the one or two types presently being used, and this will affect the flue gas treatment technology. This paper

summarized the present status of flue gas clean-up technologies covering the problems due to (1) the relatively high fuel ratio of imported coal resulting in much unburned carbon in ash aggravated by the low NO<sub>x</sub> combustion technology which tends to increase unburned carbon in ash, (2) the large nitrogen content in imported coal so that large amounts of NO<sub>x</sub> will be emitted, (3) the low sulfur content of imported coal giving rise to electrostatic precipitator back corona problems, (4) trace elements giving rise to trouble in wet flue gas desulphurization. The present flue gas desulphurization devices now operating in Japan were summarized. The present devices are wet and EPDC is now engaged in the development of dry flue gas desulphurization since large amounts of water or limestone would not be needed. A comparison was given of combustion modification technology for NO<sub>x</sub> reduction with selective catalytic NO<sub>x</sub> reduction methods. Dust removal technology was discussed including hot-side precipitators (four are in operation in Japan), fabric filters (none has been used so far in Japanese utility boilers) as well as redispersion preventive types of semi-wet electrostatic precipitators, the Boxer Charger and pulse or intermittent charging.

"Electrostatic Precipitation Studies in Japan and Australia," L. H. Fisher, Scientific Liaison Group, U.S. Office of Naval Research/Tokyo. (Comments and Discussion). Electrostatic precipitators are at present widely used in both Japan and Australia. However, at the present time, Australia is much more involved in the precipitation of fly ash from coal-burning electric power generators than is Japan. Japan, at the present time, derives only about four percent of its electric power from coal-burning power plants. Due to the difficulties foreseen in obtaining oil, it is expected that Japan will sharply increase its reliance on coal for producing electricity and Japan will have to become much more concerned with the precipitation of fly ash from coal than it has been up to now. There are at present only about four or five fly ash collecting precipitators in Japan although there are about 1300 of them in the U.S. In Japan, no more oil-burning power plants will be constructed, and plans are being made to use oil and coal as a combined fuel. Australia has huge deposits of coal and it is all low sulfur coal. There is a school of thought in Australia which feels that the role of resistivity in fly ash precipitation has been overemphasized. One group of workers has found no difficulty in precipitating low sulfur coal fly ash. Much effort has been put into the development of laboratory model furnaces to provide fly ash from coal which is characteristic of fly ash obtained from the same coal from full-scale generating plants. It is proposed that such laboratory furnaces be used to survey as yet unexploited coal deposits to help design not only the full-scale precipitators but also the furnaces as well.

"Research on Electrostatic Precipitation in Italy," A. Baldacci, Generation and Transmission Board, ENEL, G. Dinellis and F. Mattachini, Research and Development Board, ENEL, and M. Rea, Electrical Department, University of Padua. (Comments and Discussion). (ENEL is the Ente Nazionale Energia Electrica, the state owned and sole producer of electricity in Italy. In English it is referred to as the Italian National Electric Power Agency.) At the present time, about 10 percent of the electric power generated in Italy comes from coal-fired units. The use of coal for electric power generation (as well as for other purposes) will have to be increased. Italian laws on atmospheric pollution limit the maximum sulfur content in coal to one percent (no such law exists in the U.S.). The coal burned in Italian power plants is generally imported from Poland and South Africa. Because of the low sulfur content of the coal and the high CaO and high MgO and low alkali content of the resulting fly ashes, the collected dusts exhibit a resistivity in the range from  $5 \times 10^{11}$  to  $10^{12}$  ohm cm. These high resistivity dusts produce excessive sparking in electrostatic precipitators which adversely affects the collection efficiency. ENEL has tested, or is testing, many approaches to overcome this difficulty such as drastic increase in size of precipitators, the use of hot-side precipitators, chemical conditioning of flue

gases, and burning 15 to 20 percent of fuel oil. Another approach which seems to be less expensive and less difficult in operation is the pulse energization of precipitators, and the rest of the paper was devoted to this topic. At present, an Italian firm has agreed to supply a pulse power supply with a dc voltage of 0-50 kV, a pulse amplitude of 0-50 kV, a pulse duration of about 100  $\mu$ s and a pulse repetition rate of from 10 to 400 per second. The power pack is based on an oscillating circuit switched with thyristors and capacitively coupled with the dc voltage.

"Improved Precipitation by Pulse Energization," P. Lausen, High Voltage Laboratory, Technical University of Denmark. (Comments and Discussion). The advantages claimed for pulse energization of electrostatic precipitators were reviewed. Field tests, including industrial scale tests, have shown that the performance of conventional two-electrode type precipitators can be improved considerably by pulse energization, especially in the case of high resistivity dust. The importance of the different factors is not fully understood. Pulses of suitable duration and repetition rate superimposed on the dc voltage permit a high peak voltage without sparkover, improve particle charging and current distribution, and allow independent regulation of precipitator voltage and current.

"Discharge in the Presence of Dust Particles," M. Akazaki and M. Hara, Kyushu University. (Comments and Discussion). Lichtenberg figures were used to study corona discharges from small particles placed in precipitator-like field distributions.

"Effect of Back Discharge on Mechanical Behavior of Dust Particles," T. Adachi, Department of Electrical Engineering, Yamaguchi University. (Comments and Discussion). A model electrostatic precipitator was set up in which there is a wire to plate electrode system with the plate covered with mica with small holes in the mica. The mica simulates high resistivity dust and the holes simulate back discharge conditions. Also, polyethylene particles were put into the electrostatic precipitator to observe the motion of particles under back discharge conditions. Under back discharge conditions, the corona current increases with the number of pinholes. The back corona ionic wind was observed using Schlieren techniques. Observations of the polyethylene particles under back discharge conditions show that some reentrained particles return to the mica plate but some are carried away by the gas stream. The velocities of the particles are very large due to Coulomb forces and the back corona ionic wind.

## MECHANICAL FILTRATION

"Collection Performance of Air Filters," H. Emi and H. Kanaoka, Department of Chemical Engineering, Kanazawa University. (Review Talk). Collection efficiencies of clean and dust loaded filters were discussed. For the case of clean filters, expressions were first reviewed for efficiency due to direct interception, diffusion interception, gravity interception, and inertia interception separately for a single fiber, and then expressions were given for efficiencies with three of the above mechanisms and then with all four. Collection efficiency and pressure drop generally increase with time, but these changes depend on whether the collected particles are liquid or solid. Solid particles form dendrites on fibers which generally grow and play a major role in the collection of oncoming particles and in the pressure drop of a filter. Liquid particles never form dendrites but coalesce and grow to large droplets. Eventually, droplets begin to retrain and finally an equilibrium is attained between the amounts of deposited mist particles on the fibers and the reentrained droplets from them. A quantitative discussion was given for solid particles only. The effect of Brownian motion at low filtration velocity is more efficient than at high velocity.

"Recent Concepts Describing Filter System Behavior," R. Dennis and H. A. Klemm, GCA Corporation. (Review Talk). A combination of classical and new approaches was presented which permits realistic estimates of baghouse performance. Classical concepts discussed included the prediction of filter pressure loss based on fabric and dust layer permeability and the adjustments made for nonuniform distributions of fabric dust loadings and gas flows in multicompartiment systems. New concepts used include dust dislodgement by reverse flow or mechanical shaking, interaction between dust dislodgement and adhesive forces, and the relation between the size and quantity of particulate emissions and fabric properties. It was pointed out that  $K_2$  (for definition of  $K_2$ , see discussion of paper by Dennis and Dirgo above) may be a function of gas velocity or of the amount of dust on the filter, and that  $K_2$  is only one of the terms that has to be specified in describing the performance of a fabric filter. This paper treated the case of the nonideal behavior of a cloth filter. Research is underway to determine how effectively laboratory-derived filtration parameters describe field experience. Coal properties are also being studied in relation to the filterability of their resultant fly ashes.

"An Estimation Method of Pressure Loss Parameters for a Multicompartiment Fabric Filter," K. Makino and K. Iinoya, Department of Chemical Engineering, Kyoto University. (Topical Report). The design of fabric filters is not based on theoretical analysis but on experience for the following reasons:

- it is almost impossible to test the time-dependent pressure loss performance of a model filter because of the long period (one or two years) needed,
- it is difficult to describe the performance analytically because it depends on a specified combination of various kinds of fabrics and industrial dusts and,
- the correlations between cost parameters, pressure loss characteristics, and operating variables of a fabric filter system had not been established (until the present work).

Work to solve the above three problems was started in the authors laboratory in 1972. A method for determining the optimal design of a multicompartiment fabric filter was established in 1978. The method is constructed on the basis of pressure loss parameters obtained from field data of a fabric filter. Examples of application of the method with mechanical shaking or reverse air cleaning were given. The method consists of introducing two pressure loss parameters A and B, A representing the pressure loss parameter of the fabric and residual dust layer and B that of the secondary dust layer. These parameters are expressed in terms of quantities which are observable. A increases rapidly during the first few months after start up and B remains nearly constant. Application of the method have been made to commercial multicompartiment filters for periods of about 1000 days.

"Electrical Effects in Fabric Filtration: Corona Charged Fly Ash/Shaker Cleaned Fiberglass Bag," J. Abbott and L. S. Hovis, Industrial Environmental Research laboratory, U.S. Environmental Protection Agency and R. P. Donovan, Research Triangle Institute. (Topical Report). A current status report was presented of a continuing investigation on the influence of electric charges on dust particles on fabric filter performance. The work reported was carried out in a pilot plant and gave the results of providing active charging. Active charging was found to improve filter performance as reflected in reduced values of pressure drop and of  $K_2$ . The dust was charged by means of a corona wire and the study was carried out with silicone-graphite finished fiberglass using Southwestern Public Service fly ash. Studies on the effects of relative humidity and time on the enhancement of filtration performance were carried out.

"Perspectives of Filtration Technologies Development for Submicron Particulate Collection," J. R. Koscianowski, Dust Protection Division, Institute of Industry of Cement Building Materials, Opole (Poland). (Comments and Discussion). This is a mathematical modelling study designed to describe the collection of fine particles by a filter.

"Dust Removal From Filter Cloths by Impaction Acceleration and Pressure," G. Jimbo, Department of Chemical Engineering, Nagoya University. (Comments and Discussion).

"On the Effect of Dust Load on the Collection Performance of an Air Filter," C. Kanaoka, Department of Chemical Engineering, Kanazawa University. (Comments and Discussion). The growth of particle dendrites on a fiber and the time dependence of a single fiber collection efficiency under dust loaded conditions were studied using a Monte Carlo simulation technique. Fairly good agreement was obtained with experiment for the shape of dendrites and in the collection efficiency. The experiments were carried out with a filter composed of glass fibers of diameter  $20\text{ }\mu\text{m}$  and sodium chloride particles of  $1.2\text{ }\mu\text{m}$  diameter.

A summary of the session was given by Professor Whitby, a cochairman of the session. He was struck by the fact that the classical theory for determination and calculation of filter efficiency has not changed much in the last twenty years. We now have better descriptions of the filters themselves including a description of the nonideal nature of filters. The actual behavior of bag filters is determined by statistical or stochastic considerations. We are in the early stages of developing a usable approach to dust cakes and the effect of humidity on these dust cakes.

#### ENHANCEMENT OF COLLECTION

"Granular Bed Filtration," M. First and S. Rudnik, Harvard Air Cleaning Laboratory, Harvard School of Public Health. (Review Talk). Moving granular bed aerosol filters (movement is by gravity) are adaptable for high temperature gas cleaning, and with proper selection of granule materials, reactive gases as well as particles can be removed at high efficiency. Moving granular bed filters may be operated in a countercurrent, cocurrent, or crossflow mode. Crossflow operation is the simplest arrangement from a mechanical standpoint and this type of filter has been commercialized. Cocurrent filters have large dust storage capacity and lend themselves to the equivalent of cake filtration in cleanable fabric filters. In the countercurrent operation, unlike the cocurrent one, the aerosol passes from a zone of highest efficiency to a zone of lowest collection efficiency, thereby losing the advantage of large dust storage capacity. Further, granule fluidization is a danger. Nevertheless, countercurrent operation has an excellent potential for heat exchange as well as for particle collection and this is important for nuclear applications. Studies of cocurrent moving granular bed filters for coal fly ash and countercurrent beds for condensing fume particles and gas cooling were described.

"Particle Growth by Condensation and Coagulation," Y. Kousaka, K. Okuyama and T. Yoshida, Department of Chemical Engineering, Osaka Prefecture University. (Review Talk). Some possible methods to promote particle growth to enhance efficiency of industrial dust collectors were discussed. Condensation of water vapor onto dust particles is suggested to be one of the most effective methods to promote particle growth, especially when particles are small and particle number concentration is low. Brownian coagulation plays an important role in the process of particle growth when the particle number concentration is extremely high. Turbulent coagulation is effective for large particles having a broad distribution in size. Electrostatic coagulation is effective when

particles are charged with opposite signs and are separated by less than 500  $\mu\text{m}$ . The results presented are based on calculations. S. Masuda suggested that turbulence may assist electrostatic coagulation. Tassicker described an experiment at Stanford University in which bipolarly charged particles were introduced into a uniform ac field (50-60 Hz) and in which the number of particles below 1  $\mu\text{m}$  could be reduced by 30 to 40 percent with one second treatment time.

"Scrubbers for Fine Particle Control at High Pressure," S. Calvert, R. Parker and S. C. Yung, Air Pollution Technology, Inc. (Topical Report) Several theoretical models for gas-atomized scrubber performance were presented including one which appears to be best suited to high pressure operation. Predictions of particle collection efficiency and scrubber pressure drops were included.

"Semi-Wet Type ESP for Reducing Rapping Loss," Y. Kubo, Central Technical Research Laboratory, Chubu Electric Power Co., Ltd. (Topical Report). This is a report on pilot tests carried out to confirm the applicability of a hybrid type precipitator (combination of dry- and wet-type) to boiler flue gas treatment. Pilots tests were carried out with 1,350 normal  $\text{m}^3/\text{hour}$  at the No. 3 Unit of Taketoya Power Station. This unit uses oil with low sulfur content. The experimental apparatus has three stages of dry electrostatic precipitation and a single stage of wet electrostatic precipitation where a water film is formed continuously on the collecting electrodes. Results showed the effectiveness of the wet electrostatic precipitator as a supplemental aid for dry-type electrostatic precipitators. The peak dust loading during hammer rapping of the dry electrostatic precipitator was greatly reduced and it was found that collection efficiencies decrease with time in the case of the dry electrostatic precipitator, but the wet electrostatic precipitator maintains a constant performance. Additional tests aimed at studying coal-fired flue gases are being planned.

"Electrostatic Augmentation of Fabric Filtration," J. H. Abbott and L. S. Hovis, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, D. W. Van Osdell, Research Triangle Institute, and G. P. Greiner, ETS, Inc. (Topical Report). A pilot plant utilizing electrostatic augmentation of fabric filtration of flue gas from pulverized coal boilers has been constructed and operated with Teflon felt bags with electric fields (between 1.7 and 4 kV/cm) perpendicular to the gas flow. There is practically no current associated with this device. The work was carried out with two baghouses running in parallel, one with and one without electric fields, in order to get a direct comparison of performance. Each baghouse had four bags, although each baghouse has provision for thirteen bags. The system shows benefits over the conventional baghouse with respect to the rate of pressure drop increase during a filtering cycle (with an applied field of 4kV/cm, the house pressure drop increases only 25 percent as fast), residual pressure drop (the new arrangement had a residual pressure drop about 0.25 kPa lower after 400 hours of operation), and size dependent removal efficiency (the system was more efficient for all sizes).

#### ADVANCED TECHNOLOGIES AND SCIENCE

"Application of Precharger in Electrostatic Precipitators," S. Masuda, A. Mizuno, and H. Nakatani, Department of Electrical Engineering, University of Tokyo (Review Talk). The effect of prechargers on the collection performance of high resistivity fly ash by an ESP was tested using a new Boxer Charger, the Mark III, with special emphasis on studying the combined effect of precharging and the pulsing of collection fields. The Mark III Boxer Charger consists of double helical electrode units and a 40 ns high voltage pulse is used to produce the plasma. The experiment had three collection fields in series with one Boxer

Charger in the inlet duct and a second in the section between the first and second collection field. The gas temperature was about 100°C and the dust resistivity was in the  $10^{11}$  to  $10^{12}$  ohm range. Such high resistivity dust causes severe back discharge in a conventional ESP. Precharging of the dust results in a substantial increase in the apparent migration velocity of the dust in the precipitator section immediately following the Boxer Charger. However, in the subsequent collection field, the migration velocity drops to its original value. However, by applying a pulse voltage to the dc voltage of the collection fields, the apparent migration velocity becomes 50 percent larger, and the addition of a Boxer Charger in front of each collection field makes it as high as 2.9 times its original value. The advantage of precharging can be realized only when back discharge in the collection field is reduced or eliminated, and pulse charging provides an effective means for this purpose.

"Advanced Control Technology for Particles in the U.S.A.," O. Tassicker, Coal Combustion Systems Division, Electric Power Research Institute (EPRI). (Review Talk). A High Intensity Ionizer (Hi II) developed by Air Pollution Systems, Inc. and supported by EPRI was described. A cylindrical cathode is surrounded by a porous anode with electric fields of 10-12 kV/cm. Gas to be treated passes through the annular gap between the anode and the cathode and is at a temperature of 150°C and carries high resistivity particles. In order to prevent deposition of dust on the anode, purge gas can be passed through the anode. With adequate purge gas containing about four percent by weight of moisture, no sign of back corona appears. The average electric field below breakdown is about three or four times greater than that which can be sustained across a normal wire plate electrode system. Measurement of particle charges show that the ionizer charges particles to a very high level. A unit which includes the preionizer in a device for transferring the charged particles to a collector was described. Another topic covered was the minimization of rapping reentrainment losses. A significant part of the particle penetration through a dry-type precipitator occurs during rapping of the collector plates. This emission is intermittent and occurs mainly during rapping of the final collector stage. Tests on six large modern ESPs showed that about 30 percent of the penetration through cold-side precipitators and up to 85 percent through hot-side precipitators occurs as intermittent rapping puffs. Either improving sequence of rapping or use of irrigation on the collector should be considered. Finally, some concepts on an advanced hybrid electrostatic precipitator were outlined.

"Fundamental Study of a Fabric Filter with Corona Precharger," K. Iinoya and Y. Mori, Department of Chemical Engineering, Kyoto University. (Topical Report). The effects of a corona precharger on the performance of a fabric filter were studied in air of controlled humidity with a bench scale facility. Test dusts of fine calcium carbonate (mean diameter  $1 \mu\text{m}$ ) or fly ash (mean diameter  $5 \mu\text{m}$ ) were precharged by means of a positive corona and then ducted to a test fabric of polyester (Teflon) felt of  $50 \text{ cm}^2$  area. Electrostatically agglomerated chain-like particles about 1 mm long are sometimes observed just in back of the corona precharger, but most of them settle down in a settling chamber in front of the filter. The size distributions of the charged dusts were measured by a cascade impactor just in front of the test fabric and were found to be almost the same as those of uncharged dusts. The corona precharger is a short electrostatic precipitator and most of the dusts are collected at the precharger, especially for fly ash. Thus, the concentration of dust at the filter test section is very low. Uncharged dust deposits on the filter smoothly, whereas charged dust deposits smoothly in some cases, and in other cases rough surfaces of dust are formed depending on the humidity. Rugged surfaces often form at relative humidities between 50 and 75% and give rise to lower pressure drops across the filter than is the case with smooth surfaces formed with either uncharged or charged particles. The collection efficiency of a fabric filter is improved by corona precharging

and for wide ranges of relative humidity and filtration velocity. The collection efficiency becomes higher with increasing electrostatic charge on particles and is especially improved at lower dust loads. At the present time, a combination of corona and bag filter is not being used in practice. Hopefully, the combination will be applied in practice if the cost of the precharger does not prove to be excessive. If the corona discharge can result in giving a more porous deposit on the filter, then not only will the pressure drop be reduced, but the dust layer can be more easily dislodged from the fabric and lead to longer fabric life. Fabrics generally last one or two years and represent about one-third of the operating cost of the filter. (Fiber glass filters used in the power industry usually last four years.)

"Development of a Two-Stage Electrostatic Precipitator for the Collection of High Resistivity Dust," W. B. Smith and D. H. Pontius, Southern Research Institute and L. E. Sparks, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency. (Topical Report). A new two-stage electrostatic precipitator system has been developed for collecting high resistivity dusts. The first stage, or charging section, is a conventional wire and plate corona system but also contains screen grids near the passive electrode. The charging section is operated with the screens biased electrically to prevent positive ions from entering the charging zone. The second, or collector stage, resembles a conventional precipitator, but is much smaller than those generally used to collect high resistivity dusts. The collector is operated at low current levels to avoid back corona, whereas the charging section is operated at a high current density ( $50-100 \text{ nA/cm}^2$ ). Theoretical and experimental studies have been carried out and pilot-scale systems have been tested in the laboratory and were found to be effective in collecting high resistivity dusts.

"Energy Considerations on Pulse Energization of Electrostatic Precipitators," P. Lausen, High Voltage Laboratory, Technical University of Denmark. (Comments and Discussion). This paper describes an energy conserving pulse energization system involving a series oscillatory circuit in which the energy stored in the precipitator capacitance and not used by the corona discharge current can be recovered. Industrial scale tests lasting more than two years have shown that the system is reliable. Installation and operating costs show that the system should be considered for both existing and proposed electrostatic precipitators for high resistivity dusts.

#### DIESEL PARTICULATES AND HUMAN EFFECTS

"Testing of Control Devices for Diesel Particulate Emissions," D. C. Drehmel, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency and J. Dubard, G. Faulkner and J. McDonald, Southern Research Institute. (Review Talk). Diesel engines provide more miles per gallon than do spark ignition engines. For this reason it has been estimated that by 1990, twenty five percent of light duty vehicles will have diesel engines. Such engines emit fine soot which is very difficult to collect. EPA has proposed that on light duty vehicles, emissions are to be less than  $0.6 \text{ g/mi}$  by 1982 and less than  $0.2 \text{ g/mi}$  by 1985. Most automobiles satisfy the 1982 limit already, but the 1985 limit presents a problem. Although fuel and engine modifications can produce part of this reduction, there has been great interest in the use of control devices on exhaust systems. This paper discussed the use of fiber filters, gravel bed and barrier filters, and electrostatic precipitators for diesel engines. The collected material could be stored in the filter until replaced with another filter, the filter could have a catalytic coating to oxidize the collected matter or the filter could be regenerated by direct combustion of the collected material. The paper reviewed experiments carried out in many different laboratories in the U.S. For all types of filters tested, the tendency to form a dense cake creates a pressure drop problem. Only when the filter is very inefficient do pressure drops

stay in an acceptable range. Since replaceable filters have the problem of gas leakage with high pressure drop, the filter must allow lowering of the pressure drop at intervals. Thus, granular bed filters may be used as replaceable filters if a mechanism for agitating the bed to break up the cake is achieved. All other types of filters must be regenerated in place to destroy the cake by oxidation. Diesel particles have very low resistivity and this means that high voltage insulators in the precipitators will be coated with such particles and cause difficulty in maintaining the voltage on the wires. The devices would have to be designed with one of the following options: insulators placed on the clean side, insulators cleaned by liquid flushing, or insulators placed in high velocity gas streams to scour deposits.

"Measurement and Generation Mechanism of Particulates from Diesel Engines," T. Sato, Department of Mechanical Engineering, Keio University. (Review Talk). Although good progress has been made in Japan in the reduction of pollutants in passenger cars, reduction of pollution from buses and trucks with diesel engines has not been realized. This is one of the most important pollution problems in Japan. Automobile industries have directed their attention chiefly to the economic use of fuel in diesel engines instead of to the reduction of pollutant emission. Consequently, diesel engines for trucks and buses are at present of the direct injection type. The direct injection engine is, however, not suitable for the reduction of  $\text{NO}_x$ , particulates or noise. On the other hand diesel engines for passenger cars are of the prechamber type, and in this type of engine, the problem of  $\text{NO}_x$  is not as severe but the problems of better fuel economy and of low particulate emission are very difficult to solve. From 1975 to 1978 about 140 professors from mechanical engineering, chemistry, economics, and sociology worked together in an "automobile exhaust clarification study group" sponsored by a grant from the Ministry of Education and Culture (Monbusho) of about 500 million yen (about \$2.5 million). In this work, the reduction of pollutant emission from diesel engines was considered to be one of the most important problems. Some of the results achieved were discussed in this paper. Fairly useful results have been achieved to illustrate the initial combustion (premixed flame burning) process, but it is not easy to describe the phenomena of the main combustion (diffusion flame burning) process, during which the soot particulates are chiefly formed. Fundamental research has been carried out on the diesel spray combustion process. Instantaneous microscopic photographs of diesel sprays under high ambient pressure from several types of nozzles have been taken. From these and from holographs of diesel spray, it has become clear that the spray from the nozzle has a liquid jet stream on the axis of the spray. It has also been determined that in the mixing part of the region, eddies form and the first appearance of flame occurs in this part, but on the other hand, eddies cannot be seen in the initial part and the flame cannot enter into this part during the injection period. Although this research contributes to an analysis of the ignition characteristics and the initial combustion process, there is still not enough information about the main combustion process. The author classifies combustion in diesel engines in five categories:

- diffusion burning,
- premixed burning,
- luminous dots burning,
- premixed burning with luminous dots at the beginning and,
- transient burning.

In the usual diesel engine diffusion burning of spray is predominant in normal operation, but luminous dots burning occurs at starting, which is the cause of blue smoke. The characteristics of premixed flame burning such as ignition delay, ignition location, visible flame angle, flame velocity, heat release rate, etc., have been clarified substantially. Thus

the mechanism of the initial combustion process has been determined qualitatively. This contributes to the analysis of soot formation in the main combustion process. Although the mechanism of the main combustion process has been analyzed by a statistical method, experimental observations are necessary for a complete understanding. Some experimenters have been carrying out combustion research in real diesel engines. It has been found that the longer the duration of flame luminosity the higher the level of exhaust smoke. A number of other studies with diesel engines were described such as the use of a nitrogen gas quenching probe to measure the concentration of soot in a continuous spray open flame, the measurement of the spatial distributions and time histories of soot in the combustion chamber of a direct injection engine, and the measurement of the spatial distribution and time history of the concentrations of combustible gases in a swirl chamber type diesel engine.

"Lumped Mode Dynamics of Submicrometer Aerosols," K. T. Whitby, Department of Mechanical Engineering, University of Minnesota. (Topical Report). Fine particle size aerosols of diameter less than  $2\mu\text{m}$  emitted by sources or undergoing transformations in the atmosphere, may coagulate, grow by condensation, increase in number concentration by nucleation and may be subject to dilution. The present paper describes a model in which computation is simplified by lumping the entire fine particle subrange into two modes, a nuclei mode and an accumulation mode. The method has been applied to the determination of aerosol growth in coal-fired power plant plumes.

"Some Considerations on the Catalytic Conversion of Gaseous Pollutants by Carbonaceous Particulates," H. Tominaga, T. Shikada, and K. Fujimoto, Department of Synthetic Chemistry, Faculty of Engineering, University of Tokyo. (Topical Report). Soot collected from the exhaust gas of a diesel and fly ash obtained by combustion of coal were tested to see if they act as catalysts for the oxidation of sulfur dioxide and nitric oxide. The tests were carried out at 200 to  $300^\circ\text{C}$  with gas flows of NO,  $\text{SO}_2$ ,  $\text{O}_2$ , and  $\text{N}_2$  available for flowing over the particulate materials. Coal fly ash was found to be much more active than diesel soot (50 nm in diameter) in oxidation of sulfur dioxide and nitric oxide, the rate of oxidation of NO being much larger than for  $\text{SO}_2$  by fly ash. The oxidation of both  $\text{SO}_2$  and NO with fly ash as a catalyst is enhanced when both  $\text{SO}_2$  and NO are present simultaneously.

"Analysis and Toxicity of Diesel Exhaust," W. Stöber, Fraunhofer Institute of Toxicology and Aerosol Research. (Comments and Discussion). A long term inhalation study with hamsters exposed to diesel exhaust over their life time presently in progress was described. The study is designed to test whether or not diesel soot increases the carcinogenic potential of diesel exhaust. The animals are exposed to the maximum exhaust concentrations short of causing acute toxic effects and/or reducing the normal life time expectancy. This provides a period of almost two years for the tumor induction time. Substantial deposition of diesel soot occurs in the alveolar region of the hamsters lungs. The animals are subjected to regular diesel exhaust and diesel exhaust from which the particles have been removed.

"Problems of Particulate Emission from Diesel Engines," H. Hiroyasu, M. Arai and K. Nakanishi, Department of Mechanical Engineering, Hiroshima University. (Comments and Discussion). The relation between exhaust particulate emissions and combustion characteristics in diesel combustion were measured.

"Control of Diesel Particulates by a Moving Belt-Type ESP," S. Masuda, Department of Electrical Engineering, University of Tokyo. (Comments and Discussion). This paper is

discussed in the report in this issue of the *Bulletin* on "1980 Annual Meeting of the Institute of Electrostatics Japan."

"Concentration of Airborne Particles in Hospitals," I. Hayakawa and S. Fujii, Department of Architecture and Building Engineering, Tokyo Institute of Technology. (Comments and Discussion). The concentration of airborne particles in hospitals is considered as one of the hygienically important factors in estimating the quality of indoor environment. This paper presented the kinds of measuring systems and particle surveys in hospitals which have been in progress since 1976. Measuring and recording systems were installed which enabled the study of airborne particles greater than five different diameters (0.5, 1.0, 3.0, 5.0, 10.0  $\mu\text{m}$ ) simultaneously. Surveys have been carried out in five different hospitals. The system depends on light scattering. Measurements were correlated with number of persons and number of smokers. Special attention was given to surgical rooms.

#### MISCELLANEOUS REMARKS

A 326 page proceedings were distributed to the participants at the meeting. An edited version of this is being prepared. Through the good offices of Dr. Tassicker, EPRI will underwrite the publication of the edited papers.

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## APPENDIX II

### VISIT TO PROFESSOR IINOYA'S LABORATORY AT KYOTO UNIVERSITY

This appendix includes not only a description of the visit made the day before the Seminar started, but also includes impressions obtained during a visit with Professor Iinoya which I made a month before the Seminar. Since the U.S.-Japan Seminar was held, Iinoya reached the mandatory retirement age of 63 (this is the mandatory age in all national universities granting the Ph.D., with the exception of the University of Tokyo where it is 60) and retired from Kyoto University on April 1, 1981. He is now at the Department of Industrial Engineering, Aichi Institute of Technology, 1247 Yachigusa Yagus-Cho, Toyota 470-03. The subsequent material is written in the present tense and applies to the situation at the time of the Seminar. Professor Iinoya's successor had not yet been chosen as the time of this writing (May 27, 1981).

Professor Iinoya heads the koza "Process Control and Powder Technology" in the Department of Chemical Engineering at Kyoto University. A koza in a Japanese university represents an activity of some size devoted to a particular subject and usually consists of a professor, an associate professor, a number of joshus (a joshu is translated into English by the Japanese as research associate or assistant and is a tenured position equivalent to the American rank of assistant professor), lecturers, graduate students, as well as a small number of undergraduates carrying out research for writing undergraduate theses.

About twenty years ago, Iinoya spent two separate years at the Georgia Institute of Technology and another year at the University of Wisconsin. He has a very high regard for technical education in the United States, both at the undergraduate and at the graduate level, and his son is now a freshman studying mathematics at the University of Wisconsin. He feels that Japanese education is too rote-like (see opinions expressed in "Chemistry In Japan Today" in this issue of the *Bulletin*). Iinoya feels that academic opportunities for would-be faculty members are better in the U.S. than in Japan.

Iinoya organized the Society of Powder Technology, Japan many years ago. The Society is celebrating its 25th anniversary by sponsoring an International Symposium on Powder Technology, September 28-30, 1981 at the Kyoto International Conference Hall. (The '81 International Chemical Plant Engineering Exhibition, INCHEM Tokyo 81, will be held in parallel to the symposium from September 28 to October 2 in Tokyo. Over 300 exhibitors, most of them Japanese, will display and demonstrate the latest equipment, machinery, processes, instrumentation, and services related to the chemical industry, including powder technologies.) The Symposium is being organized in cooperation with the Fine Particle Society (U.S.A.).

Iinoya has also been very active in the organization and administration of the International Fine Particle Research Institute, an organization dedicated to research and development of fine particle and related technology. Members of this Research Institute consist of industrial companies (present America companies that are members include Dupont, Exxon, Monsanto, MMM, Alcoa and Eastman Kodak). Funds are provided by the companies for carrying out projects recommended by a technical committee (elected by the members) or suggested by universities. Current projects being supported include characterization, production and handling of particles, transport and dispersion of fine particles in both gases and liquids, particle-gas separation, and solid-liquid separation. The Department of Chemical Engineering, Kyoto University, is one of the five academic organizations which was involved in the founding of the Institute. [The others are the

Technical University of Clausthal (West Germany); Department of Chemical Engineering, University of Loughborough (England); Department of Chemical Engineering, City University of New York; and Department of Chemical Engineering, University of Houston.]

As may be surmised from the title of the koza, its activities very much involve powder technology and consist mainly of studies of particulate systems (including sampling and measuring), dust collection by bag filters and cyclones, mist separation by inertial forces, and powder mechanics. Powder mechanics embraces the measurement of tensile strength, compressional strength, and shear strength of powders. There is still little information available on the yield of powder layers under stress. Other activities are the study of the mechanisms of dust dislodging in bag filters and of powder feeders. The experiments carried out are of the bench type. A typical fabric studied is a combination of cloth and felt. The most important problems in fabric filters are to insure a low pressure drop across the filter even in the presence of collected dust, and to avoid plugging. The group is not primarily concerned with air pollution, but is interested in developing mechanical collectors to be used in chemical and pharmaceutical plants. Calcium carbonate is a typical dust used by the group in carrying out experiments.

Before proceeding to a detailed description of what was shown on the tour, the other members of the koza are listed:

- K. Makino, Associate Professor,
- K. Ushiki, Joshu,
- Y. Mori, Joshu,
- S. Boku, Lecturer (from China), and
- W. S. Choi, Research Assistant (from Korea).

There are also five graduate and five undergraduates in the koza.

The following subjects were demonstrated and discussed:

"Effects of a Corona Precharger on the Performance of a Fabric Filter," K. Kinoya and Y. Mori, (A paper on this was presented at the Seminar).

"Fundamental Experiments With Granular Bed Filters," K. Iinoya and Y. Mori, (The filtration performance of granular packed beds have been studied experimentally. The filter media are silica and glass beads ranging in size from one to five mm. The test dust is calcium carbonate and the filtration velocities are 20, 30 and 40 cm/s. The additional pressure drop due to the collected dust load does not depend on the filtration velocity. The collection efficiency is greater at higher velocities and for heavier dust loads in the beds.)

"Particulate Sizing Techniques: Cascade Impactor Calibrations," K. Iinoya (Experiments were carried out in which a test powder and air were passed through a cascade impactor and the wall loss was measured as a function of input mass of the particles for each of the six stages.)

"Dust Separation Performance by Cyclones," K. Iinoya and S. Boku.

"Performance of an Industrial Vacuum Cleaner," K. Iinoya and W. S. Choi, (These tests on a particular industrial vacuum cleaner were being carried out at the request of the Japanese Government).

"Fundamental Experiments on the Performance of Dust Filter Fabrics," Y. Mori, K. Makino and K. Iinoya.

"Dust Dislodging Performance of a Pulse-Jet Fabric Filter," K. Iinoya, Y. Mori and K. Makino, (A pulse-jet fabric filter can be operated at relatively high filtering velocities, and it is not necessary to stop the filtering operation for the cleaning cycle. However, there are few fundamental studies of the dust dislodging performance of pulse-jet fabric filters. In the present work it was found that: (1) there is an optimal pulse pressure for the cleaning jet, (2) the residue dust fraction approaches a constant value at high dust load, (3) the electrostatic charge generated by pulse jet cleaning without filtering flow does not have a linear correlation with the total dust load dislodged and is affected by the relative humidity of the air and the time elapsed after filtration, and (4) the relative humidity of the filtered air does not have much effect on the specific resistance of the dust layer on a wool felt at low filtering velocity.)

"Comparison of Dust Cleaning Performance of Reverse Flow and Mechanical Shaking of Fabric Filters," K. Iinoya, K. Makino, and Y. Mori. In reverse flow cleaning of bag filters, the bag is caused to collapse inward, and is sometimes referred to as collapse type of cleaning. In the collapse type of cleaning, dust removal occurs only in the initial cleaning stage, and part of the dust layer remains on the filter surface despite continuous cleaning. The existence of an optimum time for cleaning was found experimentally. In the mechanical shaking type of cleaning, removal of dust occurs throughout the entire cleaning process, so that the dust layer is almost completely dislodged. For a given cleaning time, it was found preferable to divide the cleaning into short rather than long intervals.

"Performance of Three Segment Type Mist Separator," K. Ushiki and K. Iinoya, (The collection efficiency for water droplets of a Euroform (West Germany) T 271 three segment type mist separator was measured as a function of water droplet size from 10 to 200 $\mu\text{m}$  at several velocities. The efficiency is much larger at higher velocity and reaches 80 percent between 10 and 20 $\mu\text{m}$ .)

"Performance of Louver Type Mist Separator," K. Ushiki and K. Iinoya, (The performance of louver type mist separators was studied with the blades set at an angle to the air flow. Particle collection efficiencies and pressure losses were measured for both flat and V-shape blades. The collection efficiency for droplets is much higher than for solid particles. Theoretical calculations were made of the collection efficiencies assuming potential flow outside the experimentally obtained wake. This theoretical model does not fit the experimental data too well, but a modified calculation taking turbulent mixing into account is in good agreement with the experimental observations.)

"Inertial and Gravitational Collection of a Ribbon," K. Ushiki and K. Iinoya, (Impaction efficiencies were calculated for a ribbon at various angles of inclination to the gas flow, the flow being taken as a discontinuous potential flow. Calculated efficiencies agree well with experimental results for lycopodium spores.)

"Sizing Technique of Water Droplets," K. Ushiki and K. Iinoya, (Water Droplets are sized by observing the size of a stain which they make on a film on which a dye is placed. The dye is NGB (Naphthol Green B) and the film is gelatin. The method is calibrated by having some drops containing fine polystyrene particles form deposits on the film. By counting the number of polystyrene particles the volume of the droplet can be evaluated because the concentration of polystyrene particles in the liquid is measured. The water droplet is about one half of the stain size and this ratio seems to vary somewhat with the air velocity carrying the water droplets. The smallest droplet that can be measured is 5 $\mu\text{m}$  and the method has been used to measure droplets up to 30 $\mu\text{m}$ .)

"Performance of Mist Separator with Wavy Blades," K. Ushiki and K. Iinoya, (Pressure

drop across a mist separator with wavy blades has been measured as a function of air velocity (1 to 10 m/s) for two pressures and collection efficiencies were measured.)

"Powder Mechanics," K. Makino, K. Sawai, M. Suzuki, T. Tamamura, and K. Iinoya, [An analysis was made of the static yield of a powder layer from first principles. The systematic discussion requires a representation of the geometric arrangement of the particles within the powder layer and the expression for the interparticle interaction (assumed to be given by a Lennard-Jones potential). A statistical lumped model of particle arrangement, a statistical accumulation energy distribution function, and a yield condition of constant distance moved are part of the model. The relationship between the two ways of expressing the yield of a powder in macroscopic terms, the powder yield locus (P.Y.L.) and the consolidated yield locus (C.Y.L) was elucidated. The concepts of P.Y.L. and C.Y.L. are of fundamental importance in understanding dust layers in precipitators. We were also shown two instruments for measuring the stress yields of powders, one which measures both tensile and compressional strengths, and the other which measures shear strength.]

### APPENDIX III

#### VISIT TO THE NAGOYA WORKS OF THE NIPPON STEEL CORPORATION

The host for this trip was Mr. Yoshiro Kojima, Manager, Environmental Control Office, Technical Section of the Nagoya Works of the Nippon Steel Corporation, 5-3, Tokai-cho Tokai-shi, Aichi 476 Japan. Professor S. Masuda also acted as a guide since he has been involved with Nippon Steel in the design of their electrostatic precipitators.

The Nagoya Works was started in 1961 and developed into an integrated steel plant in 1964 to produce 7.5 million tons of steel per annum. Three blast furnaces are in operation. Countermeasures against soot and dust have been undertaken for the last ten years. They have successfully controlled SO<sub>x</sub>, NO<sub>x</sub>, particulate emission and noise and vibration. Of the 90,000 Yen/ton cost for steel, 6000 Yen/ton is now being spent on pollution control.

The energy obtained from blast furnace gas, coke oven gas, and converter gas are used to supplement the external energy supplies. The Works uses 200,000 tons of fresh water per day as well as 1.2 million tons of sea water and 1.5 million tons of recycled water per day.

At the present time, 139 particulate control devices are being used in the plant. These consist of 30 precipitators, 55 bag filter units, and 42 scrubber units. The remaining units are centrifugal collectors.

Electrostatic precipitators, developed by Nippon Steel, are used for cleaning the main gas from the sinter plant and in the crushing part of sinters and in the lime kiln plant. These precipitators are a new type and are called the Electrostatic Space Cleaner Super (ESCS) and are suitable for depositing high resistivity dust from sinter plants. More than ten ESCS systems are now operating at Nippon Steel Corporation plants and are providing good results. Nippon Steel sets its own internal regulations as 0.05 gram per normal cubic meter at the emission stack. They compared the performance of a precipitator with a scrubber and baghouse arrangement and eventually discarded the scrubber arrangement because of the large pressure drop and because the use of water is a disadvantage. The baghouse was discarded because of high temperature and high humidity and the clogging of the fabric. However, there were several great difficulties in the use of

precipitators, one of them being the high value of the resistivity ( $10^{11}$  to  $10^{13}$  ohm cm). The Nihon Kogei Kogyo Company, Ltd. proposed a new type of precipitator which uses a large horizontal grounded duct of more than 2 m diameter as a collecting electrode and a very fine horizontal wire of diameter less than 0.5 mm. The voltage used was very high, 70-200 kV. The technology was later taken over by Nippon Steel. As a result of this activity, two different types of precipitators were developed. One is called the House Type ESCS and has many horizontal ducts having large spacing. It worked very well, but the construction was too complex. Therefore, a second type was developed known as the Straight Type ESCS. Further, information can be obtained from the Plant and Machinery Division, Engineering Divisions Group, Nippon Steel Corporation.

Visits were made to a blast furnace and a sintering plant. The blast furnace visited has a capacity of 10,000 tons/day and has a gas flow of 22,000 m<sup>3</sup>/minute. Bags are used to collect emissions. The blast furnace we saw is the most modern one in operation at the Works and has been operating since March 1980, and was designed to operate for ten years without stopping. The baghouse which is used in conjunction with suction is an open system, and is very expensive to operate. The sinter plant uses Australian iron ore. The ore is very variable but the Fe content is high. It is received in powder form but must be sintered.

#### APPENDIX IV

#### VISIT TO PROFESSOR MASUDA'S LABORATORY AT THE UNIVERSITY OF TOKYO

Since the work of this laboratory was described in this *Bulletin*, 5,(1) 34 (1980) in the article "Electrostatic Precipitation Research In Japan," and since discussions of papers originating in this laboratory have been given in both the present article and in the article "1980 Annual Meeting Of The Institute Of Electrostatics Japan" appearing in this issue of the *Bulletin*, only a brief supplementary account of the activities of the laboratory will be given here.

Masuda discussed the possibility of collecting ultrafine particles by electrostatic precipitation, and stated that the control of such particles (<0.01 μm) is going to be of great urgency in the next generation of circuitry, namely large scale optical circuits. Ultraclean air fabrication will be needed.

It was pointed out that in the formation of ozone and NO<sub>x</sub> from corona, a compromise is necessary. One cannot reduce both simultaneously.

A project "Basic Research on Gas Cleaning by Means of High Energy Electron Beams" was started in April 1978 and ended in March 1981. It was a study on the removal of NO<sub>x</sub> and SO<sub>x</sub> (denox and desox) from gases using electron beams. In 1972, it was discovered that SO<sub>x</sub> and NO<sub>x</sub> pollutants are rapidly converted into aerosol particles which can be easily removed by electrostatic precipitation. NH<sub>3</sub> is added stoichiometrically to the flue gas and it is found that the reaction product are solid particles of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and NH<sub>4</sub>NO<sub>3</sub>. In the present study, the possibility of removal of the resulting particles by the application of a dc electric field inside the radiation space was investigated. This might eliminate the need for an expensive electrostatic precipitator and connecting duct. Particles are, of course, deposited on both electrodes. Electron beams of energy 600 kV to 1.5 Mev were used. They passed through a thin titanium foil which was continuously

air-cooled. It was discovered that the process was enhanced by ionization by electron collision due to the dc field. This work was carried out by an interdisciplinary group of electrical engineers, high speed chemical kineticists, radiation chemists, and inorganic chemists. Most of the work was carried out at the University of Tokyo, but some was done at the Tokyo Institute of Technology and at the Japan Atomic Energy Institute.

A demonstration was given of an experiment designed to handle DT-pellets for laser fusion. Ice pellets are being used for the study. They are charged and guided by electric quadrupole fields so that a system for guiding particles into a region for laser irradiation can be investigated. The system is under development and is expected to be completed in several years. The design ensures a very high accuracy in the pellet trajectory.

A device was demonstrated for electrically separating three parts of cotton seeds, the high protein part, the useless part which is poisonous, and the shell.

A spectacular demonstration was given of a very long double helix Boxer Charger.

The above represents only a fraction of what was demonstrated.

## THE FIFTH INTERNATIONAL ACOUSTIC EMISSION SYMPOSIUM

Kanji Ono

### INTRODUCTION

The Fifth International Acoustic Emission (AE) Symposium was held in Tokyo, 18-20 November, 1980. More than one hundred and fifty participants gathered from eleven countries. The quality of the presentation was mostly good to excellent. Four invited lectures and 43 papers were given. The proceedings volume can be obtained (\$60/copy) from the Japanese Society for Nondestructive Inspection, Hashimoto Building, 5-4-5 Asakusabashi, Taito, Tokyo, Japan. The Society was the sponsor of the symposium, as well as The Third Pan Pacific Conference for Nondestructive Testing which followed.

### DISCUSSION

We shall briefly review the subject matter presented at the symposium. Invited talks by Prine and Nakasa concerned on-line weld flaw monitoring and the progress and current status of Japanese AE technology. In two other invited lectures presented at a joint session, Dau and Holler (read by Lottermoser) discussed nondestructive evaluation programs of the Electric Power Research Institute in the United States and the Institut Fur Zerstorungsfreie Prufverfahren in West Germany, respectively.

National Bureau of Standards signal analysis study was summarized by Hsu, who showed successful characterization of simulated AE sources. Problems facing practical applications of the National Bureau of Standards method also were reported as tough. Works of Waschkies and Rindorf were on wave propagation and suggested ways of avoiding pitfalls on source location. Higo discussed a method of transducer calibration.

A systematic study on stress corrosion cracking of 304 stainless steel was reported by Yuyama, who clarified the nature of AE from several corrosion mechanisms. Hydrogen gas evolution and cracking were the most prominent AE sources. Kusanagi discussed stress corrosion cracking of 3044 stainless steel in simulated boiling water reactor piping, indicating that 60  $\mu\text{m}$  cracks can be detected. Ohira presented a comprehensive study of fatigue induced AE, correlating peak load AE to plastic zone volume. A review of AE from fiber composites was presented by Duke with 89 references, followed by two papers on refractories and works on fracture of plastics and adhesive bonds. The two papers on fire bricks should be of interest to ceramists, as AE can tell the quality of the bricks.

In the area of deformation and fracture, my group at the University of California, Los Angeles, presented four papers based on Office of Naval Research sponsored research. Yamamoto described effects of nonmetallic inclusion on the fracture related AE. Anisotropic AE characteristics are traced to MnS inclusions, which cause a great difficulty in detecting the onset of ductile cracking. A similar behavior in A533B steel under tension was presented by Okajima, who varied deformation temperature from -150°C to +150°C. Temperature effect was minimal on burst emission from MnS inclusions, but continuous AE from plastic flow increased with temperature. Two papers by Hsu detailed the AE behavior of many metals and alloys in tension over wide temperature ranges. Pure metals, solid solutions with or without solute segregation and short-range ordered alloys all behaved in characteristic manner. The four papers were distributed as an Office of Naval Research technical report (ONR-TR-80-3).

Iwasaki showed the fracture of 304 stainless steel produced AE from martensitic transformation, which also was the topic of Takashima's presentation. Sano correlated the separation in linepipe steels to AE events, which originates from intergranular weakening but not necessarily from MnS inclusions. Effects of MnS inclusions were also discussed by Jaffrey and by Lottermoser. Khan presented an extensive study of AE from  $J_{IC}$  testing of several steels and established an inverse relation between AE energy sum and tearing modulus. This is important as the crack instability may be determined by AE measurements. Niituma successfully applied a multiparameter analysis method to fracture toughness testing. Kurabayashi considered brittle cracking and constructed a statistical model, whereas Ringshall analyzed crack propagation via amplitude distribution.

Fukuzawa showed AE behavior of iron single and polycrystals, indicating the usual AE peak at yielding to be due to grain boundaries. Masuda studied AE from precipitation hardened copper alloys and found AE behaviors to be quite complex.

Nakasa presented a new approach in AE instrumentation, while Takaba showed a successful remote monitoring system. Yamaguchi introduced energy moment in a source location system and also discussed the methodology of performance evaluation of AE systems. Takahashi described AE applications to geothermal wells, while Sato presented a telemetric AE monitoring system and its application to rotating machinery. Its application to spinning breakdown tests was successful.

Mori reported fatigue induced AE of 304 stainless steel and found that peak load AE activities were high during the transition from plane strain to plane stress conditions and also during Mode I to Mode III transition. Kanno and Yoshida described AE monitoring of large welded samples and 304 stainless steel weldments, respectively.

In the area of pressure vessel testing, Nakano presented an extensive testing program on a specially prepared steel vessel with artificial flaws. By imbedding materials of different toughness, it was demonstrated that AE cannot locate the incipient failure at a low toughness region. This would seriously hamper the use of AE and further studies are urgently called for. Vogelsong of the Naval Underwater Systems Center discussed corrosion related AE in aluminum vessels. Both structure-borne AE and underwater AE picked up via hydrophone were detected and traced to bad welds. Kawaguchi reported AE testing of mild steel water storage tank structures with successful conclusions.

Rodgers described various applications of AE to aerospace maintenance and structural integrity assessment, based on United States Air Force and National Aeronautics and Space Administration programs. Corrosion monitoring, weakened bond, in-flight (fatigue) monitoring, and composite evaluation were covered indicating superior cost-benefit performances of AE testing. Fujita discussed a statistical approach of AE monitoring while Obata reported AE from weld defects in a high strength steel vessel testing. Defect severity parameter was employed and compared to the NIAS method for the pressure vessel testing. Finally, AE from welding defects was reported by Huang.

Overall, this Symposium again demonstrated substantial AE research and development activities in Japan. Increased participation of overseas workers reflects the growing influence on studies elsewhere. The Pan Pacific Conference also attracted a sizeable participation and 36 papers were presented. About one-third of the papers covered acoustic and ultrasonic methods.

## EARTHQUAKES

The big news on AE in Japan was indeed big news on television and in newspapers over there. Professor Mogi of the University of Tokyo captured the sounds of "live" earthquakes. These occurred near Tokyo from late June through July of 1980. During one of the Japan Conference on Acoustic Emission meetings in November, which I attended, Professor Mogi presented the preliminary findings of the study. These earthquakes were relatively weak, the biggest being about six in magnitude, and occurred at a fault on the shallow ocean bottom. The frequencies monitored were at a few hundred Hz to several kHz. From the waveform of burst-type emission with a sharp rise time, it was reasoned that the sources were just below the ocean floor. This was in contrast to conventional seismic analysis, which concluded the sources to be six miles deep. Spatial distribution and AE uncovered the previously unknown fault. The location from the AE study was much more accurate than the usual seismic location techniques, which had to rely on distant seismic observation stations 30 to 50 miles away. Professor Mogi thinks that a network of AE sensors on the ocean floor can go a long way in predicting the incipient failure of the earth's crust. Of course, much work is needed before this type of AE detection leads to successful prediction of earthquakes. For example, a quiet period was noted prior to the occurrence of some quakes. Still, this appears to be the beginning of an interesting research work.

## APPENDIX I

#### Mailing Addresses of Principal Investigators

#### Mentioned in this Article







JAPAN-UNITED STATES CONFERENCE ON COMPOSITE MATERIALS:  
MECHANICS, MECHANICAL PROPERTIES, AND FABRICATION

Jack R. Vinson

The first "Japan-United States Conference on Composite Materials: Mechanics, Mechanical Properties and Fabrication," was held in Tokyo, Japan, at the Gakushi Kaikan during January 12-14, 1981. It was sponsored by the Japan Society for Composite Materials and aided by the Nihon Itagarasu Zairyokogaku Joseikai.

The Conference, held over a three day period, was composed of eighteen sessions: two on dynamic behavior and wave propagation, three on stress analysis and mechanical properties, fatigue properties, fracture and strength, three on metal matrix composites, ceramics and rubber composites, thermal and environmental problems, overview of composites, strength of structural elements, and four sessions on design and applications.

The meeting was formulated by the Japanese Organizing Committee, chaired by Professor Kozo Kawata, Institute of Space and Aeronautical Science, University of Tokyo, 1-6, Komaba 4-chome, Meguro-ku, Tokyo 153, and the U.S. Organizing Committee, chaired by Professor Jack R. Vinson, Department of Mechanical and Aerospace Engineering, University of Delaware. There were 130 participants to the Conference, of whom 17 were Americans.

In addition to the Conference itself, professional visits were made by the group to the laboratories of the Institute of Space and Aeronautical Sciences, University of Tokyo, and the Materials Laboratories of the University of Kyoto, the Toshiba factory near Tokyo, and three Toyota factories near Nagoya.

The Organizing Committee agreed to the excellence of the Conference, and decided to hold a second Conference. The Second Japan-U.S. Conference on Composite Materials will be held in the Williamsburg area during June 1983. Post Conference tours will include colonial Williamsburg, Busch Gardens, U.S. government laboratories near Washington, D.C., the University of Delaware, du Pont plants, Longwood Gardens, and the General Electric Company's Valley Forge space center. Any inquiries should be addressed to Dr. J. R. Vinson, Department of Mechanical and Aerospace Engineering, University of Delaware, Newark, Delaware 19711.

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## SCIENTIFIC PROGRAM

Name of Participants	Subjects
Session 1.     Dynamic Behavior and Wave Propagation I Chairmen: K. Kawata and R. L. Sierakowski	
-    K. Kawata A. Hondo S. Hashimoto N. Takeda H. L. Chung	Dynamic Behaviour Analysis of Composite Materials
-    R. L. Sierakowski N. Takeda	An Investigation of In-Plane Failure Mechanisms in Impacted Fiber Reinforced Plates
Session 2.     Dynamic Behavior and Wave Propagation 2 Chairmen: Takuo Hayashi and S. K. Datta	
-    H. Toda H. Fukuoka	Wave Propagation in Composite Cylinder
-    S. K. Datta H. M. Ledbetter V. K. Kinra	Ultrasonic Wave Propagation in Particulate and Fibrous Composites
-    Takuo Hayashi K. Arakawa Y. Morimoto	Transient Wave Propagation in Linearly Visco- Elastic Laminated Composites
Session 3.     Stress Analysis and Mechanical Properties I Chairmen: Y. Yamada and T. Mura	
-    T. Yoshino T. Ohtsuka Y. Noguchi	Stress Analysis by Photoelasticity and F.E.M. of Plane-Woven Glass Fiber Reinforced Plastic Laminates
-    Y. Yamada H. Okumura	Analysis of Local Stress in Composite Materials by the 3D Finite Element
-    H. M. Ledbetter	Elastic Constants and Internal Friction of Fiber Reinforced Composites
Session 4.     Stress Analysis and Mechanical Properties 2 Chairmen: H. M. Ledbetter and T. Akasaka	

- T. Mura Equivalent Inclusion Method in Composite Materials
- T. W. Chou Stiffness and Strength of Hybrid Composites  
H. Fukuda
- J. N. Reddy Behavior of Plates Laminated of Bimodulus Composite  
C. W. Bert Materials

Session 5. Stress Analysis and Mechanical Properties 3  
Chairmen: M. Taya and J. Shioiri

- R. B. Pipes Behavior of Discontinuous Fiber Composites: Fiber  
R. L. McCullough Orientation
- K. Shimizu The Effect of Increased Damping Matrix on the  
Damping Properties of Carbon Fiber Reinforced  
Plastics
- M. Taya Prediction of First and Second Stages of Stress-  
T. W. Chou Strain Curves of Unidirectional Short Fiber  
Reinforced Thermoplastics

Session 6. Fatigue Properties  
Chairmen: K. L. Reifsneider and T. Fujii

- K. L. Reifsneider The Mechanics of Fatigue in Composite Laminates
- T. Tanimoto Fatigue Life and Its Reliability of FRP Under  
S. Amijima Multi-Step Loading  
H. Ishikawa
- T. Fujii Fatigue Properties of Fibrous Composite Materials  
and Some Considerations on the Process of Fatigue  
Failure

Session 7. Fracture and Strength of Composites  
Chairmen: M. Suzuki and T. W. Chou

- M. Suzuki Effect of Nonhomogeneity on Elasto-Plastic Fracture  
M. Iwamoto Toughness of Composite Materials  
K. Kirimura
- R. A. Schapery Nonlinear Fracture Analysis of Viscoelastic Com-  
posite Materials Based on a General J Integral
- H. Fukuda Probabilistic Approach on the Strength of Fibrous  
T. W. Chou Composites  
K. Kawata

**Session 8. Metal Matrix Composites 1**  
Chairmen: J. N. Reddy and Y. Murakami

- S. Ochiai  
Y. Murakami      Theory and Experiments on Tensile Strength of Fibers Coated with Brittle Layer
- E. Ozawa  
O. Watanabe      The Role of the Workhardening on the Mechanical Behavior of Metal Fiber-Metal Composite
- Y. Kagawa  
H. Okuhara  
Y. Watanabe  
E. Nakata  
S. Yoshida      Some Properties of Composite Metals Reinforced with Helical Fiber

**Session 9. Metal Matrix Composites 2**  
Chairmen: S. Kohara and A. Dhingra

- S. Kohara      Compatibility of SiC Fibers with Aluminum
- S. Yajima  
K. Okamura  
T. Matsuzawa  
H. Hayase  
J. Tanaka      Continuous SiC Fiber Reinforced Aluminum
- A. Dhingra      Inorganic Alumina Fibers for Reinforcement of Metal Castings

**Session 10. Metal Matrix Composites 3 and Mortar Composites**  
Chairmen: S. Umekawa and R. A. Schapery

- S. Umekawa  
K. Wakashima      Effect of Thermal Cycling on the Interface of FRM
- I. Shiota  
O. Watanabe      Wear Properties of Graphite Fiber Reinforced Metals
- H. Yoshinaga  
H. Kurishita      High Temperature Strength of Mo-TiC Eutectic Composite
- T. Nakagawa  
A. Yanagisawa      Reinforcing Effect of Newly Developed Steel Fiber in the Steel Fiber Mortar

**Session 11. Ceramics and Rubber Composites**  
Chairmen: O. Watanabe and S. Kawabata

- J. Shioiri  
K. Satoh  
Y. Fujisawa      An Internal Friction Study of Elevated Temperature Properties of Sintered Silicon Nitrides as a Composite
- S. Kawabata  
M. Masuda  
H. Oyama  
S. Tsukada      Elastic and Viscoelastic Behaviors of Carbon-Reinforced Rubber Vulcanizates under Finite Deformation
- T. Akasaka  
S. Yamazaki  
K. Asano      Buckling of Laminated Biased Composite Strip Subjected to Bending Moment

**Session 12. Thermal and Environmental Problems**  
Chairmen: H. Yoshinaga and S. S. Wang

- K. Kondo  
T. Taki      Transverse Moisture Diffusivity of Unidirectionally Fiber-Reinforced Composites
- S. S. Wang      Hygrothermal Boundary-Layer Effects in Composite Laminates
- H. Sekine      On the Effective Thermal Conductivity of Composite Materials with Periodically Spaced Thin Insulated Inhomogeneities
- A. Kobayashi  
H. Suemasu      Generation and Conduction of Heat During Fracture in Carbon-Fiber Composites
- N. Igata  
A. Kohyama      Surface Radiation in Mo-TiC Eutectic Composites

**Session 13. Overview of Composites**  
Chairmen: R. B. Pipes and E. Nakata

- J. R. Vinson      On the State of Technology and Trends in Composite Materials in the United States
- W. J. Renton      An Overview of Hybrid Composite Applications to Advanced Structure
- B. Noton      Manufacturing Cost/Design Guide (MC/DG)

**Session 14. Strength of Structural Elements**  
Chairmen: M. Uemura and W. J. Renton

- M. Takehana  
I. Kimpara  
O. Funatogawa      Effect of Core Materials on Deformation of Hat-Shaped Composite Stiffener
- T. Hirai  
T. Senba      An Analytical Approach to Inter-Separation Behaviour of Woven-Fabric Reinforced Plastics Subjected Bending Displacement
- M. Uemura  
H. Fukunaga      Burst Strength of Filament-Wound Cylinders Subjected to Internal Pressure
- Tsuyoshi Hayashi      Buckling Strength of Cylindrical Geodesic Structures
- S. Kobayashi  
K. Sumihara  
K. Koyama      Shear Buckling Strength of CFRP Laminated Panels (1st Report)

**Session 15. Designs and Applications 1**

Chairmen: L. W. Rehfield and Y. Sakatani

- T. Hosomura  
T. Kawashima  
D. Mori      New CFRP Structural Elements
- T. Kawashima  
T. Yamamoto  
Y. Sakatani      Development of Graphite/Epoxy Tube Truss for Satellite

**Session 16. Designs and Applications 2**

Chairmen: S. Kobayashi and R. L. Daugherty

- Y. Tada  
T. Ishikawa  
E. Nakai      Tests of CFRP Spar/Rib Models with Corrugated Web
- L. W. Rehfield  
A. D. Reddy      Damage Tolerance Studies on Continuous Filament Graphite/Epoxy Isogrid Structures
- Y. Noritake  
T. Kohda  
Y. Abe  
F. Yamauchi  
S. Toyohira  
K. Mogami  
H. Arai  
N. Arata      Evaluation of CFRP Prototype Structures for Aircraft

**Session 17. Designs and Applications 3**  
Chairmen: M. Takehana and R. M. Jones

- K. Mogami  
F. Yamauchi  
Y. Sakatani  
Y. Yamaguchi      Developments on Graphite/Epoxy T-2 Nose Landing Gear Door
- F. Yamauchi  
K. Mogami  
T. Fukui  
T. Sato      Design, Fabrication and Qualification of the T-2 Composite Rudder
- F. Yamauchi  
K. Mogami  
H. Masaeda  
T. Shirata      Development of the Advanced Composite Ground Spoiler for C-1 Medium Transport Aircraft

**Session 18. Designs and Application 4 and Education**  
Chairmen: H. A. Wood and M. Morita

- F. Yamauchi  
K. Mogami  
K. Suzuki  
T. Kiho  
T. Ikuyama      Fabrication of CFRP Prototype Structure for Aircraft Horizontal Tail Leading Edge Slat Rail
- K. Takagi  
S. Idei      Development Status of a Composite Vertical Stabilizer for a Jet Trainer
- R. L. Daugherty      Composite Leaf Spring in Heavy Truck Applications
- R. M. Jones      Composite Materials Education in the United States

**Closing Remarks**      K. Kawata and J. R. Vinson

Chairmen: B. Noton and I. Miura

## XI INTERNATIONAL CONFERENCE ON DEFECTS AND RADIATION EFFECTS IN SEMICONDUCTORS

Bruce J. Faraday, Thomas A. Kennedy, and Neal D. Wilsey

### INTRODUCTION

The International Conference on Defects and Radiation Effects in Semiconductors took place in Oiso, Japan, 8-11 September 1980. This was the eleventh in a series of conferences which began at Gatlinburg, TN, U.S.A. (1959), with subsequent meetings in Kyoto, Japan (1962); Royaumont, France (1964); Tokyo, Japan (1966); Santa Fe, NM (1967); Albany, NY (1970); Reading, United Kingdom (1972); Freiburg, Federal Republic of Germany (1974); Dubrovnik, Yugoslavia (1976); and Nice, France (1978). These conferences have usually been held as satellite meetings associated with and separated by a week's interval from the larger International Congress on the Physics of Semiconductors. This year's Congress was held in Kyoto, 1-5 September, 1980.

### PARTICIPANTS

A majority of the 150 participants were Japanese (84). The United States had the second largest delegation of 18 while France had 12, the People's Republic of China, nine; the United Kingdom, seven; Federal Republic of Germany (FRG), six; U.S.S.R., three; the Netherlands, two. Other countries which were represented by one-person delegations were Argentina, Austria, Belgium, Denmark, German Democratic Republic (GDR), Ireland, Israel, Italy, and Poland. Of particular significance was the presence of the large Chinese delegation which marked the first attendance of the People's Republic of China at this conference (as well as at the Semiconductor Congress a week earlier at Kyoto). The delegation was led by Professor Wu Zi-Liang of the Shanghai Institute of Metallurgy who graduated from the Carnegie-Mellon Institute of Technology and was acquainted with several Office of Naval Research and Naval Research Laboratory metallurgists.

### ORGANIZATION

Professor R. R. Hasiguti of the Science University at Kagurazaka, Tokyo, organized and chaired the conference. In his opening remarks he extended a warm welcome to the attendees and stated that he was honored to serve in the role of organizer and chairman of the conference for the third time (Kyoto, 1962 and Tokyo, 1966). He reminisced that the opening speaker at Kyoto in 1962 was Professor G. D. Watkins of Lehigh University who was then able to positively identify the silicon vacancy by means of Electron Paramagnetic Resonance (EPR). This was the first unambiguous identification of an intrinsic lattice defect in any semiconductor and was the first of many important contributions by Watkins in his distinguished career. All of the sessions were conducted in Prince Hall with ten invited presentations being given in the full hall whereas 75 contributed papers were read in two parallel sessions in partitioned sections of the hall.

### PROGRAM

The program spanned four sessions and can be grouped into the following subject areas:

- theory, Ge, and dislocations,
- III-V semiconductors and laser-annealing,

- channeling, diamond, and contributed papers on Si, and
- process-induced defects, light ion bombardment, and II-VI compounds.

Monday's sessions covered theory, Ge and dislocations. Theory by several groups (Baraff *et al.*, Bell Laboratories, U.S.A. and Bernholc *et al.*, IBM, U.S.A.) using the self-consistent Green's function methods has reached a high degree of confidence and detail. Negative U, or two-electron trapping, properties were predicted and observed for Si. Intrinsic defects in GaP were also calculated with a challenge to the identification of the Ga-vacancy in GaP. Contributed papers on theory included a study of defects at or near interfaces. The Ge interstitial in Ge has been studied through the transmutation reactions of neutron-irradiated material (H. Saito *et al.*, Osaka University, Japan). The session on dislocations featured both microscopy studies and electrical investigations. Later in the conference a movie of an x-ray topographic study of dislocations in growing crystals was shown (J. Chikawa and F. Sato, NHK Broadcasting, Japan). Large areas of the crystal under growth could be observed at one time.

Tuesday's sessions covered III-V semiconductors and laser-annealing. Two review papers described the recent electron-paramagnetic resonance (EPR) and optically-detected magnetic resonance (ODMR) results on III-V compounds. Significant progress has been made both on intrinsic (or stoichiometric) and extrinsic (or impurity) defects in III-V compounds in the last few years (J. Schneider, IAF, West Germany). Since optical properties of III-V's are often the technologically-important ones, ODMR can have a strong influence (B. C. Cavenett, Hull University, United Kingdom). Laser annealing papers discussed the basic mechanisms involved in laser annealing as well as some experimental results on laser-annealed Si.

Wednesday's sessions, all in the morning, covered channeling, diamond, and contributed papers on Si. Channeling studies in Si doped with different impurities revealed displacements of the atoms caused by particle irradiation (F. Saris, FOM Institute, The Netherlands). The final defect structures appear to be pairs formed when acceptors trap interstitials or donors trap vacancies. An EPR study of the N defect in diamond was presented (C.A.J. Ammerlaan, University of Amsterdam, The Netherlands). The contributed papers on Si revealed a wide variety of interests and techniques. In particular the study of transition metal impurities in silicon has important technological implications.

Thursday's sessions covered process-induced defects (a new focus in the conference), light ion bombardment, and II-VI compounds. Microscopy studies show that diffusion processes induce dislocations and oxidation processes induce stacking faults (M. Watanabe *et al.*, Toshiba Inc., Japan). These problems are very important to the continuing miniaturization of integrated circuits. The II-VI session featured an ODMR study of defects in ZnSe (Lee, Dang, and Watkins, Lehigh University, U.S.A.). Optical absorption and luminescence properties were convincingly linked to point defect structures for the Zn-vacancy and vacancy-donor pair (A center). The conference summary (G. D. Watkins, Lehigh University, U.S.A.) emphasized the growing importance of process-induced defects as a theme for the 80s. The next conference will be held in Amsterdam, The Netherlands in August 1982 under the chairmanship of Professor C.A.J. Ammerlaan.

If further information about this conference is desired, please contact the chairman, Dr. R. R. Hasiguti, The Science University, Faculty of Engineering, 3 Kagurazaka 1-chome, Shinjuku, Tokyo 162.

## FIFTH INTERNATIONAL SYMPOSIUM ON AIR BREATHING ENGINES

James R. Patton, Jr.

### INTRODUCTION

The 5th International Symposium on Air Breathing Engines (ISABE) was held at the Hotel Ashok, Bangalore, India, 16-22 February 1981 with over 215 representatives of 21 countries in attendance. This series of symposia was first instituted in June 1972, to provide an international forum for discussion of scientific and technical problems pertaining to air breathing flight propulsion systems. The first ISABE was held at the Fluid Mechanics Institute in Marseilles, France and succeeding Symposia were held at Sheffield University in 1974, in Munich, Germany in 1976 and at Buena Vista, Florida in 1979. Primary attendance and participation at the symposia has included leading managers, engineers, and scientists from the participating countries throughout the world. Organization of the symposia has been handled through an International Air Breathing Propulsion Committee with the cooperation of established national and international organizations with an interest in propulsion. Recent ISABE Symposia have been held under the auspices of the International Council of the Aeronautical Sciences (ICAS) and the American Institute of Aeronautics and Astronautics (AIAA). The Fifth ISABE, in India, was cosponsored by the United Nations Educational Scientific and Cultural Organizations (UNESCO) as a part of their support for the Turbomachinery and Combustion Laboratory of the National Aeronautical Laboratory (NAL) in Bangalore. Other cosponsor hosts were the Ministry of Defense Aeronautics Research and Development Board, National Aeronautical Laboratory, Bharat Heavy Electricals, Ltd., Hindustan Aeronautic Ltd., Air India, and the Indian Airlines. Dr. Paramod A. Paranjpe, project director at the National Aeronautical Laboratory (NAL) represents India on the International Committee and he was the principal arranger and host for the National Organizing Committee of India for the Fifth Symposium.

Of the 215 delegates attending the Symposium, 95 were from India. Thirty two delegates attended from the United States and of these, 14 were sponsored by National Science Foundation travel grants. A contingent of six delegates from the People's Republic of China attended and presented nine papers. Although the U.S.S.R. had been represented in previous symposia, they did not send a delegation this year.

### ORGANIZATION OF THE SYMPOSIUM

Dr. Frederick S. Billeg of the Johns Hopkins University, Applied Physics Laboratory, served as Chairman of the U.S. National Committee and was responsible for selection of papers from the United States. Abstracts of proposed papers were solicited in mid-1980 through the AIAA Journal. Of 78 papers selected, from 19 countries, for presentation at the Symposium, 22 (28%) were from U.S. authors.

The program was organized into 12 Sessions. In general, the papers and program covered similar areas to those covered two years earlier at the 4th ISABE meeting at Buena Vista, Florida. The program has continued to be primarily aircraft turbine engine oriented, with one session devoted to ramjet missile propulsion. This emphasis has remained fairly constant in all the ISABE Symposia held since 1972, probably due to the classified nature of some of the work on ramjets as well as some lack of mission requirements in countries emphasizing that type of missile propulsion. Generally, over the past twelve years, the U.S. has conducted extensive R&D efforts in ramjet propulsion and the foreign work has usually been in the form of theoretical and analytic contributions

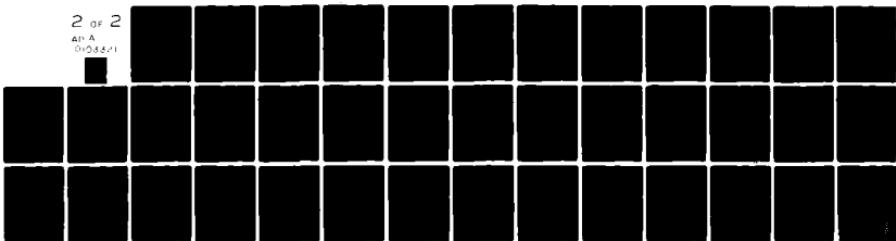
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complementary to U.S. efforts. A new session on "Instrumentation" was included this year to reflect an increased awareness of the benefits resulting when nonintrusive optical techniques are applied to specific flow phenomena and component modeling.

In operation of the symposium, the International Committee gave particular attention to a varied selection of chairmen and cochairmen from participating countries for each of the sessions. Although 28% of the papers were from the U.S., there were only two U.S. chairmen and one U.S. cochairman selected for the eleven technical sessions.

The Indian National Organizing Committee did a fine job in selecting a sight, (Hotel Ashok in Bangalore), planning the technical program, arranging social functions, and in operation of all aspects of the meeting. For the Inaugural Session Dr. S. R. Valluri, Director, National Aeronautical Laboratory at Bangalore presided. His Excellency Sri Govind Narain, Governor of Karnataka delivered an inaugural address and Smt Chandra Govind Narain inaugurated the symposium. The Keynote address was delivered by Dr. Warner Stewart, Director of Aeronautics, NASA Louis Research Center, U.S.A., on "The Future of Aeronautical Propulsion."

In addition to the formal scientific program, the Indian Committee was particularly helpful in arranging visits for interested delegates to the Turbomachinery and Combustion Lab of the National Aeronautical Laboratory (NAL) as well as to the Indian Institute of Science. There was also an active Ladies Programme, including tours and shopping, and a cultural program for all delegates at the Chowdiah Memorial Hall presenting three aspects of culture--music of India, dance of India, and brides of India.

#### TECHNICAL HIGHLIGHTS

At the Inaugural Session, the Keynote address by Dr. Warner Stewart, Director of Aeronautics at the NASA Louis Research Center, U.S.A., on "The Future of Aeronautical Propulsion" set the stage and provided an interesting introduction to the symposium. Although many of the U.S. delegates had an opportunity for prior exposure to this subject in the U.S., the talk served a very useful purpose in bringing the international group into a common focus for the following papers and informal discussions. Briefly, Dr. Stewart's approach was to summarize some of the challenges and opportunities confronting aeronautics and propulsion from the standpoint of both civil and military aviation, as well as to describe emerging technologies and the possibilities for significant advancement. He emphasized advanced materials and processes, covering such areas as powder metallurgy, single crystal and directionally solidified turbine blades, and ceramics with potential lower costs. Possible new approaches utilizing advanced computers, and electronics together with optical diagnostics were outlined for new engine controls and performance monitoring. Emphasis was given, in general, to technology useful in reducing fuel consumption and noise. Also covered were such subjects as alternative fuels, reduced clearances in rotating parts, and reduced cooling requirements.

Though most of the sessions and papers were interesting and some even stimulating, reference here will only be made to a few papers.

The session on "Operation" was in general a balanced coverage of the subject and presented in a manner to be favorably received by specialists in that area, while having some morsels of interest to the research community. The U.S. papers covered the status of power plant controls, turbine diagnostics effectiveness, life cycle cost considerations, and a review and status of environmental effects of aircraft emissions. Papers from Italy, Egypt, India, and Australia contained essentially operational-type information relative to

performance monitoring, engine maintenance, transmission fatigue, and vibration problems. Alitalia Aircraft reported on a promising engine monitoring system capable of predicting and detecting early performance degradation.

In the area of "Integration," U.S. coverage was indicative of the considerable efforts undertaken in the U.S. in recent years on inlets, flow separation studies, and ejectors. Significant advances and improvements in performance of the AV-8B aircraft by integration of the resulting new technologies were outlined in a paper by McDonnell Douglas (12). Complementary applied research efforts were described in three additional papers-covering computational tools for analysis of designs of complex 3-D inlets and exhaust nozzles (14), flow separation in inlets at incidence angles (16), and thrust increases in turbojet engines through hypermixing ejector shrouds. There were two contributions from Germany and one each from China, Netherlands, Libya, and England. The German papers were from Messerschmitt-Bolkow-Bohm GmbH, and discussed Engine-Airframe Integration for high performance military aircraft (11), and hot gas reingestion and debris ingestion during thrust reversal (13). The remaining papers in this session dealt with four different subjects, but all related to integration phenomenon: from China-development of a simplified performance calculation procedure for flow fields of supersonic ejector nozzles (15); from the Netherland-the outlook for further jet noise suppression without loss of thrust (18); Libya-the prediction of surge characteristics (19); and from Great Britain-the application of digital controls to helicopter engines.

The one session on "Advanced and Hybrid Systems" contained ten contributions on various aspects of ramjet missile propulsion; three of which were from the U.S. The U.S. coverage included reports of ramjet air induction system design (21), basic work on mathematical modeling and mapping of pressure and gas concentration fields of dump combustors (22), and another new analysis of base flow with and without combustion (27). Two Chinese papers represented recent research in areas reminiscent of U.S. work in the 1960s, i.e., ramjet trajectory simulation tests (23) and experimental studies of a solid rocket ramjet (25). An Indian paper covered theoretical analysis of a fuel rich rocket ramjet engine utilizing metalized propellants and this represented current technology (24). The two Australian papers represented competent investigations, complementary to earlier work, on solid rocket thrust enhancement by ejector augmentation (26), and the factors affecting after body drag, i.e., boundary layer drag (28). In the Swiss paper (29), Professor Berchtold has reintroduced application of a wave pressure exchanger (Comprex), with conventional turbo machines as a possibility for a light aircraft application. The paper from Israel (29A) covered a theoretical and experimental investigation for computing internal reacting flows and use of LDV for sudden expansion flow verification experiments.

Of seven papers in the session on "Turbines and Cooling," only one was from the U.S., and it presented a good summary of transpiration cooling concepts for turbine blades (32). This covered new insights on heat transfer effectiveness and erosion, corrosion, deposition resistance characteristics pertaining to possible future generation aircraft and industrial turbine engines using coal or coal-derived fuels. Other contributions from China, the UK, Egypt, and India were generally analytic investigations on turbine stator cascades (30), optimum design considerations (31), and film cooling effectiveness (33,34,35). Another contribution from Belgium (36) summarized turbine blade cooling research at the Von Karman Institute.

In the session on "Instrumentation" there were four papers presented and they covered work in the area of machinery wear (37), compressor duct system response to unsteady flows (39), determination of rotor tip clearances (40), and a review of combustion diagnostics utilizing the CARS technique (41). The Australian paper on wear, described a

procedure for measurement of optical density values of wear particle depositions by use of a Ferrograph manufactured by Foxboro, Inc. of the U.S. In the report on a digital technique for the analysis of the response of compressor/duct systems in unsteady flow, it is interesting to note that Dr. Peacock of Cranfield University is presently on sabbatical leave and stationed at the Navy Postgraduate School in Monterey California where he is involved with similar U.S. Navy programs sponsored by ONR. The third paper from West Germany covers another crucial area-namely rotor tip clearances-and it was devoted to two measuring techniques developed by MTU-Munich, Germany, i.e., (1) an electromechanical gauge (EMAG) useful for stationary and slow transient operating conditions and, (2) a temperature-compensated capacity technique (Coulomb system) useful for tip clearances during fast transient conditions. The review paper on the CARS technique covered ONR supported effort and it is interesting to note that summaries of this work have been presented in a number of international meetings in the past year. This one in Bangalore, however, was noteworthy since it was in India that the Raman effect was first discovered in 1928 by Chandrasekhara Venkata Raman.

There were ten papers covering "Combustion and Design Problems," with only one of them from the U.S. on the fundamental aspects of flame stabilization (48). Here, models that were previously developed to predict extinction limits in turbulent combustible mixtures have been applied to available experimental data, and the factors affecting blowout velocities and limits were outlined. Other presentations covered the basic areas of combustor flow characterization and modeling, including swirling flows (43, 44, 49, and 50), mixture entrainment (47), spray characterization (52), and altitude relighting performance (53). An interesting review was given of the factors limiting Turbine Inlet Temperatures (TIT), relative to combustor types, pollutant considerations, pattern factors, etc., and predictions made for TIT limitations in future engine development.

In the session on "Materials," there were two contributions from India and one each from Sweden and China. One Indian paper discussed a photoelastic investigation of stress distribution and concentration factors in gas turbine components (55). The second paper related to control of amplitude and shaft vibration by influence of O rings to control damping coefficients in a squeeze film-mounted ballbearing (56). A related paper from China (57) described squeeze film bearing applications to turbofan engines, and covered both rig and engine tests. The Swedish paper discussed the potential for high temperature metal matrix composites, (particularly tungsten wire reinforced iron and nickel alloy), in meeting advanced turbine engine requirements (54).

There were four papers presented in the session on "Vibration and Flutter" and they were closely related to important areas of concern as outlined in a recent ONR/AF/NASA Colloquium held in January of this year. A paper on the effects of mistuning on blade torsional flutter (59) gave new insights on both aerodynamic and mechanical coupling among all the blades of a fan where individual blade inertias, frequencies, or damping could be considered. Paper (62), on the influence of gyroscopic forces on the dynamic behavior of rotating blades, concluded that, in principle, an oscillatory instability may develop by cantilever blades attached to a spinning and precessing rotor.

In session 11, on "Cascade Flow," there were no U.S. papers presented, although one was submitted, covering the influence of turbulence on laminar separation on an airfoil. In seven other papers, the general theme was theoretical and correlation studies emphasizing numerical methods and solutions for 2-D cascade flows and 3-D methods for blade row flows. One report covered an experimental investigation of cascade flow fields by blade surface measurements, schlieren photos, and LDV.

Somewhat more advanced, and practical type, investigations were covered in the session on "Compressors," at least in the three U.S. papers (72, 75, and 78). One paper reported on a theoretical and experimental study, performed for NASA and ONR, on solid particle trajectories and locations of collisions between the solid particles and the blade surfaces. The presence of solid particles in the working media often leads to performance deterioration, both structurally and aerodynamically. Blade erosion estimates were reported, based on blade pressure distribution and total pressure loss coefficient parameters. Another area of investigation with practical and operational overtones covered a study of the effects of water ingestion into jet engine compressors. In this effort, predictive tools and models were developed for studying performance deterioration with water ingestion; these involved such considerations as blade droplet interactions, entrainment processes, and casing and hub boundary region flows.

#### IMPACT OF U.S. PAPERS

American participation and leadership has been evident in all aspects of the ISABE Symposium series of meetings since inception in 1972. The fifth ISABE is no exception, regardless of the meeting location, when one considers that U.S. participation represented 15 percent of the delegates in attendance and 28 percent of the papers selected for presentation. Since the series started in 1972, the quality of papers from abroad has steadily improved and today the various programs in air breathing propulsion are complementary. There is a very active following of U.S. research and development efforts on the part of all participating countries. They keep informed of problem areas we encounter and have displayed keen interest in directing their theoretical and analytic abilities to help understand and solve the problems. As a result, there is very good integration of programs in all the participating countries.

#### BASIC RESEARCH HIGHLIGHTS

The program contained reports of both fundamental and applied research efforts although very little of the work would be classified basic research as such. Participant delegates from abroad generally gave emphasis to theoretical studies and checking results against known applied or experimental data, usually generated in the United States.

#### OPPORTUNITIES FOR COLLABORATION

During the Fifth ISABE Symposium Meeting, one afternoon was reserved for the Delegates to visit the Turbomachinery and Combustion Laboratory of the National Aeronautical Laboratory (NAL) located several miles from the meeting location in the Hotel Ashok in Bangalore. The NAL dates back to the early 1960s and is one of a group of laboratories established by the Council of Scientific and Industrial Research to pursue aerospace and engineering research. It has about 1400 employees in five scientific divisions. The Turbomachinery and Combustion Laboratory, set up in 1975, is a part of the Propulsion Division, which comprises about 100 staff. This laboratory contains various facilities (Combustion and Dynamics Lab, Subsonic and Transonic Tunnels, Compressor and Turbine Research Rigs) and associated test and diagnostic equipment for investigations of all aspects of Turbomachinery. All facilities in the laboratory were designed around a centralized compressed air source constituting the wind tunnel center of NAL. The laboratory is very well equipped and appears to have a competent and versatile staff to pursue their objectives of experimental research to generate design data with scale models, development of computer-based design aids, and to develop novel techniques for component improvement and diagnostics. NAL is partially supported by UNESCO. In the area of aeroelasticity and blade flutter, it appears that cooperative programs with U.S. counterparts, i.e., Stevens Institute of Technology, could prove of value.

## ACCOMPLISHMENTS AND CONCLUSIONS

This was the first time this symposium was held on the Asian continent and it was evident that the representation of the participating countries did not suffer. This was due in large measure to the organization of the Indian National Organizing Committee as well as the International Sponsors. The symposium was well organized and the technical content generally covered important problem areas.

The U.S. continues to play a prominent role in the international airbreathing engine community. This role, however, would be strengthened if U.S. representation were more formally organized before further steps are taken to formally organize the international groups. This would permit a more balanced input from both the government and industry.

In a business meeting of the Delegates, it was decided to accept an invitation from France to hold the sixth ISABE in Paris. Following that, the seventh ISABE symposium will probably be held in the People's Republic of China. Although the Chinese presently do not support extensive programs in Air Breathing Propulsion and are generally not as advanced in their work, they do have potential for conducting theoretical studies. The ISABE series of symposia has played an important role in their progress; they have attended the last three symposia and are becoming familiar with U.S. programs. In addition, they have invited several groups from the U.S. to visit their facilities in China.

## SCIENTIFIC PROGRAM

### SESSION I: INAUGURAL SESSION

W. Stewart      Key note address: The Future of Aeronautical Propulsion

### SESSION 2: OPERATION

Chairman  
Professor M. Berchtold, ETH, Zurich, Switzerland

Co-Chairman  
Professor U. Ghezzi, Italy

- 1 R. J. Smuland                  Powerplant Control - "It's a new ball game"
- 2 L. T. Barnes                  Effectiveness of Turbine Diagnostics System
- 3 B. Signori  
F. Traversa                  Engine Performance Monitoring System Expansion on Alitalia Aircraft
- 4 I. O. Natale  
V. P. Riviello                  Diagnostic and Monitoring of Turboprop Engines
- 5 R. L. Spencer                  The Engineering Basis for the Application of Life Cycle Cost or Supportability Criteria to Gas Turbine Engines

- 6 A. H. Badr  
M. T. E. Mayah Contribution to the Improvement of the Classical Method of Maintenance of Aircraft
- 7 R. C. Oliver Environmental Aspects of Aircraft Emissions
- 8 K. Srinvasa  
M. L. Sidana Analysis of Vibration Related Failures in Aero-Turbo-Shaft Engines
- 9 K. F. Fraser  
C. N. King Helicopter Transmission Fatigue Life
- 10 P. D. McFadden Investigation into the Vibration of the Starter Gearbox of an Aircraft Turbine Engine

### SESSION 3: INTEGRATION

**Chairman**

Vivek R. Sinha, Aeronautics Research & Development Board, India

**Co-Chairman**

Dr. K. Richey, Wright Patterson Air Force Base, USA

- 11 W. Schreiber  
E. Heinz A Look at Comprehensive Engine Airframe Integration for High Performance (Modern) Military Aircraft
- 12 C. C. Cassmeyer Technology Pays Off on the AV-8
- 13 W. Kurz Comparisons of Model and Flight Testing with respect to Hot Gas Reingestion and Debris Ingestion during Thrust Reversal
- 14 E. Tjonneland  
S. F. Birch Development and Validation of Computational Tools for Analysis-based Designs of Complex 3-D Inlets and Exhaust Nozzles
- 15 H. Shen, C. Tong  
T. Shyur  
N. Kee The Sweep Finite Element Method for Calculating the Flow Field and Performance of Supersonic Ejector Nozzles
- 16 A. K. Jakubowski  
R. W. Luidens Flow Separation in Inlets at Incidence Angles
- 17 B. H. Goethert Noise Attenuation and Associated Thrust Increase of Turbojet Engines Through Hypermixing Ejector Shrouds
- 18 S. L. Sarin  
W. B. de Wolf Jet Noise Suppression for Low-Bypass Engines - Have We Reached a Dead End?
- 19 S. M. Ramachandra Prediction of the Surge Characteristics of Turbojet Engines
- 20 M. P. Perks  
T. G. Morton The Digital Control Systems as Part of an Integrated Accessory Fit for Future Engines

#### SESSION 4: ADVANCED AND HYBRID SYSTEMS

Chairman  
M. Pianko, ONERA, France

Co-Chairman  
T. V. Vareed, Hindustan Aeronautics Ltd., India

- 21 J. G. Bendot  
E. Heinz Jr. Ramjet Air Induction System Design for Tactical Missile Applications
- 22 R. S. Boray  
C. Chang Flowfield Studies of Dump Combustors
- 23 C. Shih-Si A Ramjet Trajectory Ground Simulating Test
- 24 S. Krishnan  
V. Ramanujachari  
K. S. Padivar  
R. Natarajan Performance Analysis of Primary and Secondary Systems of Rocket-Ramjet Engine Burning Fuel-rich Metallized Propellants
- 25 C. Da-Ming  
T. Ye-Ing  
L. Uyi-Ing  
S. Zin-Zyn Experimental Study of Combustion in Solid Rocket-Ramjet Engine
- 26 S. A. Fisher  
R. D. Irvine Air Augmentation of Rockets for Low Speed Application
- 27 F. S. Billig  
J. A. Shetz A Simplified Technique for the Analysis of Base Flow With and Without Combustion
- 28 W. H. Schofield Factors Affecting Afterbody Drag
- 29 M. Berchtold A New Breed of an Air Breathing Engine
- 29A J. B. Greenberg  
Y. M. Timnat Sudden Expansion Injection for Ram Rockets

#### SESSION 5: TURBINES AND COOLING

Chairman  
Dr.A. Gopalakrishnan, Bharat Heavy Electricals Ltd., India

Co-Chairman  
Dr. Y. Kakehi, Japan Defence Agency, Japan

- 30 W. Zhong-Chi Calculation of the Effects of Combined Blade Twist and Lean on the Performance of Turbine Stator Cascade with Long Blades

- 31 Man-Chu Ge The Optimum Design and Performance Estimation of Transonic Axial-Flow Turbine
  - 32 R. Raj S. Moskowitz Transpiration Cooled Blade-A Technology of the Future Generation Aircraft and Industrial Gas Turbine Engines Using Coal or Coal-derived Fuels
  - 33 N. Hay Discrete Hole Film Cooling of Turbine Blades
  - 34 A. A. M. El Ehwany M. A. El Nasre Film Cooling Performance by Injection Through Discrete Holes
  - 35 B. R. Pai R. Lakshminarayana Film Cooling Performance of Liner Cooling Devices
  - 36 P. M. Ligrani . Turbine Blade Cooling Research at the Von Karman Institute for Fluid Dynamics

## SESSION 6: INSTRUMENTATION

**Chairman**  
**J. Patton, Office of Naval Research, U.S.A.**

**Co-Chairman**  
**Professor G. J. Walker, University of Tasmania, Australia**

- 37 G. Mc Vea  
M. L. Atkin      The Analytical Ferrograph: Some Factors Affecting Deposit Formation
  - 38 H. Habig  
H. R. Leistner      A System to Measure and Analyze the Pressure and Swirl Distribution in Intake Flows
  - 39 D. K. Das  
R. E. Peacock      A Digital Technique for all Analysis of the Response of Compressor/Duct Systems in Unsteady Flow
  - 40 H. Knoll  
K. Schedi  
G. Kappler      Two Advanced Measuring Techniques for the Determination of Rotor Tip Clearance during Transient Operations
  - 41 A. C. Eckbreth  
R. J. Hall  
J. A. Shirely      Investigation of Coherent Anti-stokes Raman Spectroscopy (CARS) for Practical Combustion Diagnostics

## SESSION 7: COMBUSTOR DESIGN PROBLEMS I

**Chairman**  
**Dr. G. Kappler, MTU, West Germany**

**Co-Chairman**  
**Professor Gad El Mawla, Ainshams University, Egypt**

- 42 Withdrawn

- 43 F. M. Joubert  
H. V. Hattingh      The Analysis of a Reverse Flow, Annular Combustion Chamber
- 44 N. Syred  
A. C. Styles      Application of Modulatable Cyclone Combustors to form a Basis for Low Pollutant Emission Gas Turbine Combustors
- 45 A. A. Rizk  
K. S. Koddah  
E. G. W. Younan      The Effect of Slot Geometry on the Performance of Supply Air Grills and Combustor Holes
- 46 B. G. A. Sjoblom  
Odgers      Factors Limiting Turbine Inlet Temperatures
- 47 K. Sridhara  
M. S. Chidananda      Fresh Mixture Entrainment in a Jet Curtain Flame-holder

#### **SESSION 8: COMBUSTOR DESIGN PROBLEMS II**

**Chairman**  
Professor J. Swithenbank, University of Sheffield, UK.

**Co-Chairman**  
Professor J. Odgers, Laval University, Canada

- 48 D. R. Ballal  
A. H. Lefebvre      Some Fundamental Aspects of Flame Stabilization
- 49 W. P. Jones  
J. Mc Guirk      A Comparison of Two Droplet Models for Gas Turbine Combustion Chamber Flows
- 50 T. C. Claypole  
N. Syred      The Combustion Modelling of Swirling Flows for Gas Turbine Combustors
- 51 Withdrawn
- 52 U. Ghezzi  
A. Coghb  
C. Brioschi  
F. Gamma      L. D. A. Techniques in Spray Characterization
- 53 Y. F. Zu  
Z. X. Huang  
S. M. Wang  
Y. Z. Wang      The Effect of Oxygen Concentration Distribution on Altitude Relighting Performance of a Turbo-Jet Engine Combustor

#### **SESSION 9: MATERIALS**

**Chairman**  
Air Vice Marshal S. N. Roy Choudhary  
Gas Turbine Research Establishment Bangalore, India

Co-Chairman  
Professor B. E. L. Decker  
University of Saskatchewan, Canada

- 54 L. O. K. Larsson High Temperature Metal Matrix Composites for Gas Turbines
- 55 R. Padmanabhan Photoelastic Investigation of Stress Distribution around Inclined Cut-outs in Gas turbine Components  
K. Ramachandra  
V. Maruthi  
B. J. Raghunath Subjected to Inplane and Bending Loads
- 56 V. A. Kumar Influence of O-Rings on the Behavior of Damping Coefficient in a Squeeze Film Mounted Ball Bearing
- 57 W. M. Li Investigation of the Squeeze Film Bearing on a  
C. Shan-Zhi  
Sun Yen biao  
Wu Zhen qui Two-spool Turbo-Fan Engine

#### SESSION 10: VIBRATION AND FLUTTER

Chairman  
Professor F. A. E. Breugelmans,  
Von Karman Institute of Fluid Dynamics, Belgium

Co-Chairman  
Professor S. Soundranayagam  
Indian Institute of Science, India

- 58 S. Fleeter Cascade Modelling of Supersonic Flutter
- 59 A. V. Srinivasan Effects of Mistuning on Blade Torsional Flutter  
A. Kurkov
- 60 S. S. P. Rao Self-Excited Vibration of Turbomachine Blades  
V. Mukhopadhyaya  
J. S. Rao
- 61 S. Yokai Reduction of Strut Induced Rotor Blade Vibration  
S. Nagano with the Modified Stator Setting Angles  
Y. Kakehi
- 62 F. Sisto The Influence of Gyroscopic Forces on the Dynamic  
A. T. Chang Behavior of Rotating Blades

#### SESSION II: CASCADE FLOW

Chairman  
Professor C. H. Wu, Academia Sinica,  
People's Republic of China

Co-Chairman  
Professor E. Nilsson, Chalmer's University of  
Technology, Sweden

- 63 B. E. L. Deckker  
J. Iwamoto Flow in Annular Diffusers with Two Vortex Distributions at Entry
- 64 A. M. Elzahaby On the Solution of Navier Stokes Equations of the Flow in Turbomachines
- 65 H. H. Fruhauf Numerical Computations of Compressible Steady Cascade Flows
- 66 J. Starke The Axial Velocity Density Ratio and the Axial Velocity Density Distribution in Axial Flow Compressors and Cascades
- 67 H. A. Schreiber  
H. Starken Evaluation of Blade Element Performance of Compressor Rotor Blade Cascades in the Transonic and Low Supersonic Flow Range
- 68 K. Celikovsky Investigation of Flow through Supersonic Axial Compressor Cascades
- 69 W. Z. Sadeh  
P. R. Sullivan Turbulence Influence on Laminar Separation on an Airfoil
- 70 W. Quin-han  
N. X. Chen Finite Difference Solution of Full-potential Equation for Cascade Flow along Arbitrary Stream Filament of Revolution in Turbomachinery, using Nonorthogonal Curvilinear Coordinates and Nonorthogonal Velocity Components

#### SESSION 12: COMPRESSORS

Chairman  
Robert O'Brien, United Technologies Research Center, USA

Co-Chairman  
Dr. K. Celikovsky  
Aeronautical Research and Test Institute, Czechoslovakia

- 71 R. X. Cai The Accuracy of Mean Stream Line Method in Subsonic and Transonic Regions
- 72 B. Lakshminarayana  
R. T. Govindan Analysis of Boundary Layer and Wakes for a Compressor Rotor Blade
- 73 J. Paulon  
D. Dehondt Problems Encountered in Measurement and Interpretation of Experiments with Advanced Axial Compressors

- 74 J. Colpin  
M. Malina  
P. Van Wambeke  
D. Van Ham  
  
Blade Row Variable Distance Effects on Compressor  
Unsteady Phenomena
- 75 W. Tabakoff  
C. Balan  
  
Effects of Solid Particles Suspended in Fluid Flow  
through an Axial Flow Compressor Stage
- 76 A. F. Abdel Azim  
M. I. I. Rashed  
  
Particulate Flow in Centrifugal Compressors used  
in Helicopters
- 77 J. P. Bertoglio  
J. Mathieu  
G. Charnay  
  
Effects of Coriolis Forces on the Turbulent Field  
inside Centrifugal Impellers
- 78 T. Tsuchiya  
S. N. B. Murthy  
  
Model for Axial Compressors Operating with Water  
Ingestion

## THE FIRST CHINA-JAPAN-U.S.A. SEMINAR ON ORGANOMETALLIC CHEMISTRY

Minoru Tsutsui and Charles D. Schaeffer, Jr.

(Editorial Note: Professor Minoru Tsutsui of Texas A&M University recently contributed to ONR Tokyo this account of the first trilateral People's Republic of China (PRC)-Japan-USA Seminar on Organometallic Chemistry. Professor Tsutsui, an esteemed productive ONR contractor for several years, has since passed on. This report is published herewith; there was no editing.)

The first trilateral People's Republic of China (PRC)-Japan-USA Seminar on Organometallic Chemistry, held June 9-13, 1980, in Beijing, has been unanimously acclaimed a success by participants and observers from all three countries. This historic encounter (*C & En News*, June 11, 1980) among organometallic chemists of widely differing backgrounds and philosophies revealed a common thread linking all: a recognition of the overwhelming potential of organometallic chemistry to play a significant role in solving some of the important problems facing mankind today.

The conference was the culmination of several years of intensive efforts on behalf of principal coordinators Minoru Tsutsui of Texas A & M University, Y. Ishii of Japan, and Y. Z. Huang of the PRC. Other coordinators were Richard Heck, (University of Delaware), R. Okawara (Okayama Science University, Japan), and Y. D. Hu and Y. Y. Jing (Chinese Academy of Sciences, PRC). Both academic and industrial concerns were represented by the total delegation.

A total of twenty seven plenary lectures were delivered, while a popular poster session included displays authored by eleven Americans and Japanese, and coauthored by nearly 150 Chinese. Approximately ninety seven chemists attended the technical sessions, twenty from the USA, sixty from the PRC, fifteen from Japan, and two observers from West Germany and Norway. The plenary lectures and poster sessions witnessed presentations illustrative of the broad scope of organometallic chemistry, including synthesis, structural elucidation, reactivity, reaction mechanisms, applications of organometallic reagents in organic synthesis, catalysis, activation of small molecules, and industrial and medicinal uses. Panel discussions on various aspects of main group and transition metal organometallic chemistry, held in the evening following one of the lecture sessions, proved to be a valuable forum for both meeting foreign colleagues and for exchange of scientific ideas. The entire conference in Beijing was conducted in English, and the U.S. participants remarked on the exceptional proficiency with this language which the Chinese delegates exhibited.

While the Chinese received all presentations with enthusiasm, they seemed extremely interested in developments relating to applications of organometallic reagents to organic synthesis, hydroboration, homogeneous and heterogeneous catalysis, and structural determination by x-ray crystallography.

Due to drastic curtailment of scientific activities and education during the ten year Cultural Revolution, Chinese organometallic chemistry is today in its infancy. Although a small amount of the requisite equipment is now being purchased, the acute shortage of personnel trained in the operation and maintenance of this sophisticated instrumentation is temporarily hindering progress. Advanced academic degrees equivalent to a masters or doctorate are currently not being awarded, and it will most likely be several more years before students will be receiving them.

Nevertheless, the severe handicap of training and age (the average age of the Chinese chemists in the group was claimed to be 55) has not dulled their enthusiasm for chemistry. The Chinese encountered by the U.S. delegates appeared well-versed in most chemical literature. The libraries of Beijing University and Shanghai Institute of Organic Chemistry contained relatively complete holdings of most major foreign journals, essentially all of which were recognized to be inexpensive photo-offset copies of originals.

The delegates were privileged to tour several universities, institutes, and industrial facilities, including Beijing University, the Beijing Institute of Chemistry, Shanghai Institute of Organic Chemistry, and the Yan Shan Petroleum Chemical Corporation (outside of Beijing). In China, universities assume the traditional role of teaching in combination with independent study or research, concluding (at least in the near future) with an advanced degree in one's area of specialization. On the other hand, institutes offer no degree or course work. Instead, a principal investigator takes on one or more co-workers in a research capacity, not unlike Western postdoctoral fellows. Both types of facilities are taking initiatives to obtain first-rate analytical and spectroscopic equipment for their workers. Multinuclear NMR, IR, X-ray, gas chromatographic, and related instrumentation is either already present or is on order from well-known Japanese, European, or American manufacturers. As an amusing paradox to this seemingly headlong rush towards modern instrumentation, participants noted at one institute that on a shelf right below a well-known, highly sophisticated computerized plotter rested an abacus, one of the most ancient of calculators ("Just in case the abacus fails, the computer is ready," one U.S. observer remarked). This scene is perhaps symbolic of recent Chinese philosophy; a recognition that the traditions of thousands of years of Far Eastern life must somehow be blended to accept modern Western ideas and technology, with this amalgamation being at once rapid but not detrimental to cultural integrity.

The Chinese coordinators provided excellent programs both during and after formal technical sessions. In addition to the standard, but highly justifiable "tourist attractions" (such as the Great Wall, Ming Tombs, and the Summer Palace), the delegates were permitted to visit areas normally off limits to tour groups. The underground defense works is a complex labyrinth of subterranean, heavily reinforced tunnels, which apparently lie beneath many of China's largest cities. These civil defense tunnels are equipped with foodstuffs, air filtration systems, and modest living accommodations for thousands of people for periods of several days. Most Western observers, however, felt that these tunnels would be ineffective protection against direct hits or nuclear attack. Two receptions in Beijing's Great Hall of the People were also memorable. The second, celebrating the conclusion of the symposium, was televised nationally in China. In attendance was Mr. Wan Li, the Vice Premier of Science and Technology of the People's Republic of China, who will succeed Mr. Deng Xiao Ping, the First Vice Premier, in August. Following this reception, all delegates viewed the priceless collection of art objects encompassing the culture of all thirty Chinese provinces.

Despite the successful technical sessions, elaborate banquets, and well-organized sightseeing, perhaps the major highlight of the trip was in personal contact with the Chinese people. All participants commented on the extremely friendly, courteous, and hospitable nature of their hosts. Many local people would not only stop and stare at the Westerners, but those with adequate English would inquire at length about conditions and everyday life in the West. Political propaganda was absolutely minimal during the visit.

The first organometallic chemistry conference in China closed on a high note with a farewell banquet in Shanghai. As Professor Rowland Pettit noted in his toast (one of many on that festive occasion), this meeting was an "experiment," an experiment which worked

well, and one which would provide a basis for further such endeavors in the near future.

The seminar was sponsored by the Chinese Academy of Sciences, the Chinese Chemical Society, the Japan Society of Organic Synthesis, and the American Chemical Society. Consideration is being given to hold the second C-J-U Seminar on Organometallic Chemistry at Shanghai in 1982.

### PARTIAL SCIENTIFIC PROGRAM

#### Lecture Session

Opening Remarks: Y. Z. Huang (Chairman)  
M. Tsutsui  
Y. Ishii

#### Lecture Session I (Chairman: R. Okawara)

Name of Participants	Subject
- M. Kumada	Chiral ferrocenylphosphines and $\beta$ -(N,N-dimethylaminoalkyl) phosphines: Highly efficient ligands for some homogeneous catalytic asymmetric syntheses.
- R. F. Heck	Palladium-catalyzed syntheses of polyfunctional aliphatic compounds from vinylic halides.
- J. X. Lu	Mixed transition-metal cubane-line clusters--some structural considerations in attempted synthesis of new imperfect clusters.

#### Lecture Session 2 (Chairmen: R. Heck and Y. J. Gu)

- R. Pettit	Bridging methylene complexes and their possible role in the Fischer-Tropsch reaction
- A. Yamamoto	Oxidative addition reactions of low valent transition metal complexes with olefins and carboxylic esters
- Q. R. Cai	Coordination catalysis by transition metal complexes
- J. J. Eisch	Metallocyclic pathways in organometallic reactions
- R. H. Grubbs	The reactions of metallocycles

#### Lecture Session 3 (Chairmen: J.J. Eisch and J. Tsuji)

- R. West	Recent advances in the chemistry of polysilanes
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- Y. Z. Huang Studies on the application of arsenic ylides in organic syntheses
- H. Sakurai Reactions of allylsilanes and application to organic syntheses
- R. J. Angelici Synthesis and reactivity of dithiocarbene complexes
- A. Suzuki Synthetic application of organoboranes readily obtainable from olefins via hydroboration

#### Lecture Session 4 (Chairmen: Q. R. Cai and A. Tolman)

- M. D. Rausch Recent advances involving the chemistry of early transition metal alkyls, aryls, carbonyls and vinyl monomers
- Y. J. Gu The studies on the new reactions of pyridine copper chloride complex and lateral metallation and alkylation of alkylpyridines
- D. Forster Mechanistic pathways in the catalysis of olefin hydrocarboxylation by metal complexes
- J. Tsuji Application of palladium catalysis to natural product syntheses

#### Lecture Session 5 (Chairmen: A. Yamamoto and R. Pettit)

- C. A. Tolman Steric and electronic effects of phosphorous ligands on the chemistry of transition metal complexes
- S. Inoue Organometallic catalysis in carbon dioxide fixation
- Y. Y. Jiang New polymer-supported metal catalysts for hydrogenation, hydrosilylation and conversion
- T. Saegusa Synthetic reactions by means of copper complexes
- D. E. Bergbreiter Polymer activated catalysts

#### Lecture Session 6 (Chairman: R. West)

- A. Wojcicki Cycloaddition reactions of transition metal-o-allyl- propargyl and related complexes
- H. Kurosawa Activation of thallium-carbon bond with reducing agents: Implication in synthetic and environmental chemistry
- A. Nakamura Preparation and reactions of 1, 3-diene complexes of Zr and Hf
- K. Itoh Palladium(0) olefin complexes and their role in homogeneous catalysis by way of metallocycle intermediates

**Closing of the Seminar:**      M. Tsutsui (Chairman)  
    Y. Ishii  
    Y. Z. Huang

Proceedings of the Seminar will be published. Inquiries on this publication should be made to Professor Charles D. Schaeffer, Jr., Department of Chemistry, Elizabethtown College, Elizabethtown, PA 17022, U.S.A.

## INTERNATIONAL MEETINGS IN THE FAR EAST

1981-1983

Compiled by Seikoh Sakiyama

It is intended to update and augment this list in future issue of the Scientific Bulletin. The assistance of Dr. T. D. Grace, Australian Embassy, Tokyo, and Dr. M. J. McNamara, New Zealand Embassy, Tokyo, in supplying a listing of meetings in their countries is deeply appreciated. Similarly, the assistance of Dr. Robert Stella, American Embassy, New Delhi (formerly in Seoul), in supplying a listing of meetings in Korea is deeply appreciated. Readers area asked to notify us of upcoming international meetings in the Far East which have not yet been included in this list.

1981

Date	Title	Site	For information, contact
June 28-July 3	2nd Asian-Pacific Corrosion Control Conference	Kuala Lumpur, Malaysia	APMACA Science Center 35-43, Clarence Street Sydney, N.S.W. 2000
July	International Conference on Thermodynamics and Kinetics of Metallurgical Processes	Bangalore, India	Dr. G.N.K. Iyengar ICMS 81 Department of Metallurgy Indian Institute of Science Bangalore 560012
July 27-August 1	The 4th International Congress of Biorheology	Tokyo, Japan	Japanese Society of Biorheology Physics Laboratory Keio University 4-1-1, Hiyoshi Kohoku-ku, Yokohama 223
August 9-15	International Conference on Deformation Processes in Tectonics	Alice Springs, Australia	Dr. G. P. Price CSIRO, Division of Applied Geomechanics, P.O.Box 54 Glen, Waverley, Vic 3149
August 10-14	International Congress of Pharmacology	Sydney, Australia	Australian Academy of Science P.O.Box 783, Canberra City A.C.T. 2601
August 17-21	21st Conference on Physical Science & Engineering in Medicine and Biology	Melbourne, Australia	Mr. K.H. Clarke Dept. of Physical Sciences Cancer Institute 481 Little, Lonsdale St. Melbourne, Vic, 3000

1981, continued

Date	Title	Site	For information, contact
August 18-21	2nd Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists	Adelaide, Australia	Dr. J. Haigh P.O. Box 42, Unley South Australia 5061
August 21-28	XIII International Botanical Congress	Sydney, Australia	Executive Secretary Dr. W.J. Cram School of Biological Sciences University of Sydney N.S.W., 2006
August 24-26	Vth International Conference of Electrical Bio-impedance	Tokyo, Japan	Prof. K. Nakayama Dept. of Electrical & Engineering Sophia University 7 Kioicho, Chiyoda-ku Tokyo 102
August 24-28	4th International Conference on Rapidly Quenched Metals	Sendai, Japan	The Japan Institute of Metals Aramaki Aoba, Sendai Miyagi 980
August 24-28	International Federation of Automatic Control (IFAC)8th Triennial World Congress	Kyoto, Japan	Prof. Y. Sawaragi Dept. of Applied Mathematics and Physics Faculty of Engineering Kyoto University Yoshida-Honmachi Sakyo-ku, Kyoto 606
August 25-28	International Conference on Computing for Development	Bangkok, Thailand	Dr. Kanchit Malaivongs ICCD Secretary, Asian Institute of Technology P.O.Box 2754, Bangkok
August 26-27	Symposium on Stress Analysis for Mechanical Design 1981	Sydney, Australia	The Conference Manager Institution of Engineers Australia 11 National Circuit Barton, A.C.T. 2600
August 31-September 5	IACEI Symposium on ARC Volcanism	Hakone, Japan	Volcanological Society of Japan Earthquake Research Inst. University of Tokyo 1-1-1, Yayoi Bunkyo-ku Tokyo 113

1981, continued

Date	Title	Site	For information, contact
September 4-5	'81 Kobe International Symposium on Aging	Kobe, Japan	Dr. S. Yoshida Japan WHO Association Kyoto Shoko-Kaigi Bldg. Karasuma-dori Egisugawa-agaru Nakagyo-ku Kyoto-shi, Kyoto 604
September 4-8	9th ICAS-XXII CSI (9th International Conference on Atomic Spectroscopy and XXII Colloquium Spectroscopum Internationale)	Tokyo, Japan	The Japan Society for Analytical Chemistry 9th ICAS-XXII CSI Gotanda-Sanhaitsu, 26-2 1-chome, Nishi-gotanda Shinagawa-ku, Tokyo 141
September 6-18	XVIIth IUFRO (International Union of Forestry Research Organization) World Congress	Kyoto, Japan	Government Forestry Experiment Station The Ministry of Agriculture Forestry and Fisheries 1 Matsunosato Kukizaki-mura, Inashiki-gun Ibaraki 300-12
September 13-18	The 10th International Congress of Electro-encephalography and Clinical Neurophysiology	Kyoto, Japan (undecided)	International Conference Organizers, Inc. Crescent Plaza 103, 2-4-6 Minami-Aoyama, Minato-ku Tokyo 107
September 17-21	The 14th World Congress of International League against Epilepsy and the 13th Symposium of the International Bureau for Epilepsy	Kyoto, Japan	International Conference Organizers, Inc. Crescent Plaza, 103, 2-4-6 Minami-Aoyama, Minato-ku Tokyo 107
September 20-23	1981 International Symposium on Gallium Arsenide and Related Compounds	Kanazawa, Japan	Prof. H. Yanai Dept. of Electronic Engineering University of Tokyo 7-3-1, Bongo, Bunkyo-ku Tokyo 113
September 20-25	12th World Congress of Neurology	Kyoto, Japan	Simul International, Inc. No.9, Kowa Bldg., 1-8-10 Akasaka, Minato-ku Tokyo 107

1981, continued

Date	Title	Site	For information, contact
September 21-24	International Rock Mechanics Symposium on Weak Rock -Soft, Fractured and Weathered Rock- (ISRM)	Tokyo, Japan	Japan Society of Civil Engineers 1-chome, Yotsuya Shinjuku-ku, Tokyo 160
September 21-25	The VIth International Symposium on Glycoconjugates	Tokyo, Japan	Prof. T. Osawa, Division of Chemical Toxicology and Immunochemistry Department of Pharmacy University of Tokyo 7-3-1 Hongo, Bunkyo-ku Tokyo 113
September 21-26	3rd International Conference on Environmental Mutagens	Tokyo, Japan	The Third International Conference Mutagens P.O. Box 236, Kyobashi Tokyo 104-91
September 23-25	Australian Society of Nephrology joint meeting with Cardiac Society	Brisbane, Australia	Dr. B.M. Saker Renal Unit, Royal Perth Hospital, Perth, WA 6000
September 28-30	International Symposium on Powder Technology '81	Kyoto, Japan	The Society of Powder Technology, Japan Shibunkaku Kaikan Sekidencho, Tanaka Sakyo-ku, Kyoto 606
October 4-7	4th Congress of International Society for Laser Surgery	Tokyo, Japan	Narong Nimsakul, M.D., Secretary General 4th Congress of International Society for Laser Surgery Dept. of Plastic Surgery School of Medicine Tokai University Boseidai, Ischara-shi Kanagawa Pref. 259-11
October 7-9	IIth International Symposium on Industrial Robots (and Robot Exhibit)	Tokyo, Japan	Mr. Y. Komori Japan Industrial Robot Association Kikai Shinko Bldg. 3-5-8, Shiba-Koen Minato-ku, Tokyo 105

1981, continued

Date	Title	Site	For information, contact
October 9-10	2nd International Symposium on Endocytology in Anesthesia & Surgery	Kyoto, Japan	Prof. T. Oyama Dept. of Anesthesiology School of Medicine University of Hirosaki Hirosaki-shi, Aomori 036
October 11-23	International Union Conservation of Nature	Christchurch, New Zealand	Lincoln College Christchurch
October 18-25	15th Annual Conference on Law of the Sea	Seoul, Korea	Korea Ocean Research and Development Institute P.O. Box 17, Yang-Jae Seoul
October 26-30	FAI the 74th General Conference, 1981 (International Aeronautical Federation)	Tokyo, Japan	Japan Aeronautic Association 1-18-2, Shinbashi Minato-ku, Tokyo 107
November 20	International Conference on Large High Voltage Electric Systems	Kyoto, Japan	CIGRE Committee Institute of Electrical Engineers 12-1, Yuraku-cho 1-chome Chiyoda-ku, Tokyo 100
December 7-11	Seminar on Estuaries their Physics, Chemistry Biology, Geology and Engineering Aspects	Goa, India	Dr. R. Sen Gupta Convener, Seminar on Estuaries National Institute of Oceanography Dona Paula, Goa-403004
December (tentative)	Ninth International Symposium on Comparative Endocrinology	Hong Kong	Prof. B. Lofts Dept. of Zoology The University of Hong Kong

1982

Date	Title	Site	For information, contact
February (tentative)	7th Australian Electron Microscopy Conference	Canberra, Australia	Australian Academy of Science P.O. Box 783, Canberra City A.C.T. 2600

1982, continued

Date	Title	Site	For information, contact
March 22-26	International Symposium on Hydrothermal Reactions	Yokohama, Japan	Prof. Shigeyuki Sohmiya Research Laboratory of Engineering Materials Tokyo Institute of Technology 4259, Nagatsuta-cho Midori-ku, Yokohama Kanagawa 227
April/May (tentative)	Second International Workshop on the Malaco- fauna of Hong Kong and South China	Hong Kong	Dr. B.S. Morton Department of Zoology The University of Hong Kong
May 10-15	General Meeting of the International Association of Geodesy	Tokyo, Japan	Assistant Prof. I.Nakagawa Geophysical Institute Faculty of Science Kyoto University Oiwake-cho, Kita-Shirakawa Sakyo-ku, Kyoto 606
May 11-14	International Cryogenics Engineering Conference	Kobe, Japan	Prof. H. Nagano The Institute for Solid State Physics University of Tokyo 7-22-1 Roppongi, Minato-ku Tokyo 106
May 17-20	The 3rd World Conference on Lung Cancer	Tokyo, Japan	S.G. Prof. K. Suematsu The Secretariat of the 3rd World Conference on Lung Cancer National Cancer Center 5-1-1 Tsukiji, Chuo-ku Tokyo 104
May 23-28	16th International Con- gress of Dermatology (CID)	Tokyo, Japan	Japan Convention Service, Inc. Nippon Press Center 8F 2-2-1, Uchisaiwai-cho Chiyoda-ku, Tokyo 100
May (tentative)	35th Annual Metals Congress	Sydney, Australia	Australasian Institute of Metals P.O.Box 263, Bondi Beach N.S.W. 2026

1982, continued

Date	Title	Site	For information, contact
June 6-10	Symposium on Chemical Kinetics Related to Atmospheric Chemistry	Japan (undecided)	Dr. Hajime Akimoto The National Institute for Environmental Studies 16-2, Yatabe-cho Ogawa Tsukuba-gun, Ibaraki 305
June 7-11	9th International Congress on Electrocardiology (23rd International Symposium on Vectorcardiography)	Tokyo, Japan	Tokyo University School of Medicine 7-3-1 Hongo, Bunkyo-ku Tokyo 113
June 7-11	4th International Symposium on the Genetics of Industrial Microorganisms	Kyoto, Japan	GIM Japan National Committee Microbiology Research Foundation 2-4-6 Yayoi, Bunkyo-ku Tokyo 113
June 27-July 2	5th International Conference on Geochronology, Cosmochronology & Isotope Geology	Nikko, Japan	Geological Survey of Japan Agency of Industrial Science and Technology 1-1-3 Yatabe-Higashi Tsukuba-Gun, Ibaraki 305
June (tentative)	12th International Conference of Biochemistry	Sydney, Australia	Prof. W.H. Elliot Biochemistry Department University of Adelaide Adelaide, S.A. 5000
July 5-10	VI International Symposium on Solute-Solute-Solvent Interactions	Osaka, Japan	Prof. H. Ohtaki Tokyo Institute of Technology at Nagatsuka Dept. of Electronic Chemistry Nagatsuta, Midori-ku Yokohama 227
Mid-July (tentative)	The 5th International Congress of Plant Tissue	Yamanashi, Japan	Assistant Prof. A.Komamine Dept. of Botany Faculty of Science University of Tokyo 7-3-1, Hongo, Bunkyo-ku Tokyo 113
August 15-21	International Biochemical Congress	Perth, Australia	Australian Academy of Science and International Union of Biochemistry P.O. Box 783, Canberra A.C.T. 2601

1982, continued

Date	Title	Site	For information, contact
August 15-21	Fourth International Symposium on Antarctic Earth Sciences	Ingle Farm, Australia	Dr. J.B. Jago South Australian Institute of Technology P.O. Box 1, Ingle Farm South Australia 5098
August 16-20	Fourth International Symposium on Antarctic Earth Sciences	Adelaide, Australia	Dr. R.L. Oliver Department of Geology University of Adelaide Adelaide, S.A. 5001
August 22-26	The 7th Asia and Oceania Congress of Endocrinology	Tokyo, Japan	Prof. K. Shizume Dept. of Medicine 2 Tokyo Women's Medical College Kawadacho, Shinjuku-ku Tokyo 162
August 22-27	4th International Conference on Organic Synthesis (IUPAC)	Tokyo, Japan	Prof. T. Mukaiyama Dept. of Chemistry Faculty of Science University of Tokyo 7-3-1, Hongo, Bunkyo-ku Tokyo 113
August 27-30	Second International Symposium on Molecular Beam Epitaxy and Related Clean Surface Techniques	Lake Kawaguchi Japan	Prof. R. Ueda Department of Applied Physics School of Science and Engineering Waseda University 4-1, Ohkubo 3-chome Shinjuku-ku, Tokyo 160
August 29-September 4	The 5th International Congress of Pesticide Chemistry, IUPAC	Kyoto, Japan	Rikagaku Kenkyusho (The Institute of Physical and Chemical Research) 2-1 Hirosawa, Wako-shi Saitama 351
August (tentative)	The Royal Australian Chemical Institute 7th National Convention	Canberra, Australia	Executive Secretary, RACI HQ 191 Royal Parade Parkville, Vic. 3052
August (tentative)	1982 International Conference on Solid State Devices	Tokyo, Japan	The Japan Society of Applied Physics Kikai-Shinko-Kaikan 5-8, 3-chome, Shibakoen Minato-ku, Tokyo 105

1982, continued

Date	Title	Site	For information, contact
August 23-27	The 8th Congress of International Ergonomics Association	Tokyo, Japan	Masamitsu Oshima, Director The Medical Information System Development Center Landick Akasaka Bldg. 2-3-4, Akasaka, Minato-ku Tokyo 107
September 5-10	International Conference on Magnetism-1982 (ICM-1982)	Kyoto, Japan	Prof. J. Kanamori Faculty of Science Osaka University Toyonaka, Osaka 560
September 6-10	International Conference on Nuclear Physics in the Cyclotron Energy Region	Osaka, Japan	Prof. M. Kondo Research Center for Nuclear Physics Osaka University Yamada-kami, Suita-shi Osaka 565
September (tentative)	6th International Symposium on Contamination Control	Tokyo, Japan	Japan Air Cleaning Association 6-7-5, Soto-Kanda Chiyoda-ku, Tokyo 101
October 4-6	3rd International Dental Congress on Modern Pain Control	Tokyo, Japan	Japan Convention Service, Inc. Nippon Press Center 8F 2-2-1, Uchisaiwai-cho Chiyoda-ku, Tokyo 100
October 24-29	Second International Conference on Stability of Ships and Ocean Vehicles  Architects of Japan	Tokyo, Japan	Prof. S. Motora The Society of Naval Architects of Japan  15-16, Toranomon 1-chome Minato-ku, Tokyo 105
November 17-19	3rd JIM (Japan Institute of Metals) International Symposium	Japan (undecided)	The Japan Institute of Metals Aza Aoba, Aramaki Sendai-shi, Miyagi 980
undecided	International Conference on Mass Spectroscopy	Hawaii, U.S.A.	Prof. T. Tsuchiya Basic Science Lecture Room Chiba Institute of Technology 1-17-2, Tsudanuma Narashino, Chiba 275

1982, continued

Date	Title	Site	For information, contact
undecided	International Rehabilitation Medicine Association Fourth World Congress	Sydney, Australia	Prof. G.G. Burniston Dept. of Rehabilitation Medicine Prince Henry Hospital Little Bay, N.S.W. 2036
undecided	Workshop on Marine Microbiology	Seoul, Korea	Korea Ocean Research and Development Institute P.O.Box 17, Yang-Jae Seoul

1983

Date	Title	Site	For information, contact
August 1-7	International Association for Dental Research	Sydney, Australia	Mr. Scott Gotjamanos Dept. of Pathology Perth Medical Centre Verdon Street Nedlands, W.A. 6009
August 17-24	4th International Congress of Plant Pathology	Melbourne, Australia	Mr. B. Price Victorian Plant Research Institute Dept. of Agriculture Victoria, Swan Street Burnley, Vic. 3121
August 21-27	5th International Congress of Immunology	Kyoto, Japan	The Japanese Society for Immunology Institute of Virus Research Kyoto University Kawaracho, Shogoin Sakyo-ku, Kyoto 606
August 27	Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption	Jakarta, Indonesia	Dr. Didin Sastrapradja Indonesian Institute of Sciences LIPI, JL Teuku Chik Ditiro 43 Jakarta
August 27-31	25th International Geographical Congress	Sydney, Australia	Australian Academy of Science P.O. Box 783 Canberra City, A.C.T. 2601

1983, continued

Date	Title	Site	For information, contact
August 28- September 2	29th International Congress of Physiology	Sydney, Australia	Australian Academy of Science P.O.Box 783, Canberra City A.C.T. 2601
August 28- September 3	The 3rd International Mycological Congress (IMC 3)	Tokyo, Japan	Prof. K. Tsubaki Institute of Biological Sciences The University of Tsukuba Sakura-mura, Ibaraki 305
August (tentative)	International Solar Energy Congress	Perth, Australia	Mr. P. Driver Honorary Secretary P.O. Box 123 Nedlands, W.A. 6009
October (tentative)	8th International Conference on Calcium Regulating Hormone	Kobe, Japan (tentative)	Prof. T. Fujita 3rd Division Dept. of Medicine School of Medicine Kobe University 7-13, Kusunoki-cho Ikuta-ku, Kobe 650
October 29- November 3	71st FDI Annual World Dental Congress (Fédéra- tion Dentaire Internationale)	Tokyo, Japan	Japan Dental Association (Japanese Association for Dental Science) 4-1-20, Kudan-kita Chiyoda-ku, Tokyo 102
undecided	13th International Con- gress of Chemotherapy	Melbourne, Australia	Dr. B. Stratford St Vincent's Hospital 59 Victoria Parade Fitzroy, Vic. 3065

1984

Date	Title	Site	For information, contact
Late August- Early Sept.	The 3rd International Congress on Cell Biology	Kyoto or Kobe, Japan	Japan Society for Cell Biology Shigei Medical Research Institute 2117 Yamada Okayama 701-02

1985

Date	Title	Site	For information, contact
October 15-18	International Rubber Conference	Kyoto, Japan (tentative)	The Society of Rubber Industry, Japan Tobu Bldg., 1-5-26 Motoakasaka, Minato-ku Tokyo 107

## CHEMISTRY IN JAPAN TODAY: AN INTERVIEW WITH O. HAYAISHI AND M. MUKOYAMA

(Editor's Note: The following is an excerpt of a translation of an anonymous interview with Professors Osamu Hayaishi and Mitsuaki Mukooyama, which was published in Japanese in Volume 36 (4) of *Chemistry* 1981. This article may be interesting to the reader as it portrays some aspects of the Japanese perception of science in Japan today.)

Professor Hayaishi was born in California in 1920 and graduated from the School of Medicine of Osaka University in 1942. After working in the Bacteriology Department of Osaka University, the Wisconsin Enzyme Research Institute, the Department of Microbiology at the University of California, and the U. S. National Institutes of Health, he became Assistant Professor of Microbiology at the University of Washington, and subsequently became Director of Toxicology at the U. S. National Institutes of Health. At present, he is a Professor in the School of Medicine of Kyoto University. He has received awards from various countries, such as the Japan Academy Prize (1969), the Order of Culture (Japan) (1972), the Chiba Gold Prize (England), the Mayor of Paris Bronze Prize (France), the Biochemistry Prize of the New York Academy of Sciences and the Diaz Prize (Spain). He is a member of the U. S. National Academy of Sciences, the Japan Academy and the Academy of Germany.

Professor Mukooyama was born in 1927 in Nagano Prefecture, Japan. He graduated from the Department of Chemistry of the Tokyo Institute of Technology. After being an associate professor in the Faculty of Science at Gakushuin University (Tokyo) and a professor in the Faculty of Science at the Tokyo Institute of Technology, he assumed his present position as professor in the Department of Chemistry, Faculty of Science, University of Tokyo. He received the Progress Award from the Chemical Society of Japan (1957), the Yamaji Natural Science Promotion Award (1965) (Japan), the Society Award of the Chemical Society of Japan (1973), the Naito Research Prize (1975) (Japan), and the Toray Science Technology Award (1978) (Japan). He received an Honorary Doctorate of Natural Science from the Munich Technische Hochschule (1975).

### - "CHEMISTRY IN JAPAN IS AT A FAIRLY GOOD LEVEL"

INTERVIEWER: Recently, chemistry in Japan has been rated as being at the top level in the world. Would you please comment on the standard of chemistry in Japan from an international point of view?

MUKOYAMA: As far as organic chemistry is concerned, an increasing number of young Japanese scholars are becoming active in this field, and I think that fairly good research is being carried out. As the quality of Japanese research has been steadily improving, much Japanese research has been cited in journals. In certain fields at large conferences, Japanese lectures sometimes attract more interest than do lectures from other countries.

HAYAISHI: In the fields of biochemistry and molecular biology, I am certain that not only is the quantity of research being carried out getting larger but that the quality is improving. But whether Japanese workers in these fields are leading the world in carrying out top-level research is a different story.

MUKOYAMA: At the moment, there are few Japanese scholars in chemistry at the top level, but in the future many Japanese scholars may be expected to be world leaders. I rate the present Japanese level of research in chemistry as "fairly good."

HAYAISHI: The same situation exists in the fields of arts and sports as well as in the academic world. We have been trying to catch up with the level of Western countries. It may be rather presumptuous to say that we are about to surpass the West, but that time is imminent. I think that Japan has come to that stage.

- "SEPARATION OF RESEARCH AND EDUCATION MAY PRODUCE A SLOW DOWN OF ACTIVITY"

INTERVIEWER: How should we proceed to break the final barrier to reach the top level in the world both in performance and in reputation?

MUKOYAMA: In European countries, stars are fostered by providing extensive support. For instance, in France if there is a young and competent professor at the University of Strasbourg, he may be given an opportunity to become a professor at the Collège de France and to do whatever he wishes with abundant support in order to become a star. I think that the situation in Japan would be very much improved if the same kind of possibilities were available. What do you think?

HAYAISHI: A similar system exists at the Max Planck Research Institutes in Germany. These research institutes were established for Nobel prize winners and prospective Nobel prize winners, and such people are allowed to devote themselves to research with abundant aid and financial support. But it seems that this system has its problems. Two or three scholars who have recently moved from Europe to America have pointed out that this system has caused a decline in the general educational level and in clinical medicine in Germany. It means that it may be good to have a facility where scholars can devote themselves solely to research, but the separation of research and education creates an eventual slowdown of scholarly activity.

MUKOYAMA: Doesn't the postdoctoral system in Germany help to inject new blood into research?

HAYAISHI: I don't think that the postdoctoral system is used as much in Germany as it is in the United States. If a leading scholar of Nobel prize winner stature is appointed as director of one of the Max Planck Research Institutes, his associates serve him like servants and after the director retires, they cannot manage by themselves. In other words, the famous Japanese proverb, "a thousand soldiers die to raise one general to fame," may not be a good motto to follow. We have to take similar tendencies in Japan into consideration. But generally speaking, I think it is a good idea to give an opportunity to capable people to devote themselves to independent research without worrying about their future.

- "THE TIME HAS COME TO EVALUATE WORK HONESTLY WITHOUT REGARD TO THE INSTITUTION WHERE IT WAS CARRIED OUT"

INTERVIEWER: How does one go about selecting a competent person in Japan? With our system, it must be very difficult to evaluate and select people.

HAYAISHI: Japanese customs do make this very difficult. First of all, domestic appraisal for research should be based on the Japanese proverb, "a certain penalty for bad performance and a certain reward for good performance." At present, there is a tendency in Japan for work in science, as well as in music and painting, not to receive good evaluations until after good evaluations have been received in foreign countries. Japan is said to be operating at an international level, but we are a little bit behind in having confidence in our own assessment of work carried out in this country.

MUKOYAMA: But don't you think that this situation has improved considerably?

HAYAISHI: Yes, there is a great difference between the past and the present.

MUKOYAMA: Recently, Japanese have started to evaluate good work as good regardless of where the work was carried out. My situation allowed me to become independent at an early stage and I started to do my own research independently at a fairly early age. But now there are more young scholars, and they are having difficulty finding positions. To my regret, there is a shortage of academic positions for young people.

HAYAISHI: People in chemistry have told me of such difficulties.

MUKOYAMA: Even a competent person will not be able to develop his ability to be a leader if he has to work under a boss. We assume a different attitude if we are working under a boss than if we are ourselves a boss, even in a small institution. For this reason, it would be good if a fundamental research institution in organic chemistry were to be established so that many capable scholars could do work there independently. Is there room for expansion in biochemistry?

HAYAISHI: The establishment of new medical schools in various prefectures has contributed greatly to the large demand for biochemists in the medical field. Besides, institutions under the supervision of the Ministry of Public Welfare, such as national hospitals, have attached importance to fundamental research and many national and prefectural heart and neurology research institutes have been established. Industry has also become very involved in the life sciences. For these reasons, the employment situation for biochemists has been very good for the last few years.

#### - "THE POSTDOCTORAL SYSTEM SHOULD BE USED MORE EFFECTIVELY"

INTERVIEWER: Associate professors and assistants (in Japan, an assistant in an academic department corresponds to the American assistant professor) seem to have serious worries about their future. There is a serious problem due to an excessive number of Ph.D's.

HAYAISHI: Is that so? I think that their future is bright as long as they do good work.

MUKOYAMA: I think that is correct. There is now a trend to hire a capable person from any university as well as one who received his training from our own university.

HAYAISHI: That is true. In our research laboratory, the research staff and graduate students are graduates of various universities such as the University of Tokyo, Kyoto University, Osaka University, Gifu University, and so on. A graduate of a Faculty of

Science was appointed as associate professor and a graduate of a School of Agriculture became a lecturer in the School of Medicine in Kyoto University. I assume, however, that other fields are still affected by academic cliques.

MUKOYAMA: Do you think that it is impossible to adopt the U. S. postdoctoral system in Japan? Most of my work has been carried out with graduate students. But if we could have people with experience for two or three years under a postdoctoral system, we would then be able to undertake different kinds of problems than we now work on. But under the present circumstances in Japan, we have to look for permanent positions for people within two to three years after the completion of the Ph.D. So, except for two or three young staff members, the research group is always comprised of people studying for Ph.D's and the master's degree, and I am the only one in the group that is getting old.

HAYAISHI: Ochoa (Editor's Note: Severo Ochoa, was born and educated in Spain, Spanish-U.S. physician and biochemist, and a co-winner with Arthur Kornberg of the 1959 Nobel prize for medicine for discovery of an enzyme in bacteria that enabled him to synthesize ribonucleic acid in a test tube) said, "I don't work with graduate students. Only postdocs are my partners." So your suggestion about postdocs sounds ideal. The postdoctoral system seems to be utilized more effectively in the biochemistry field in Japan than in other fields. The postdoctoral system in Japan as is sponsored by the Japan Society for the Promotion of Science (JSPS), or by various foundations, is not well regarded by young people. Japanese like to work in one organization for their entire career and to have a stable position. This tendency makes Japanese remain in one location and become an expert in a specific field. Actually, for future growth, young people should have a wide variety of experience. Some Japanese are actively working abroad in biochemistry and molecular biology in institutes headed by scholars of Nobel prize level. But in most cases, the Japanese are not leaders of projects and they are working under other people. Japanese are well appreciated as soldiers but not as captains. After their return to Japan, it is questionable whether they can cope with the difficult problems of being a professor and giving direction to others. I fear that they are not being trained to be leaders. A big difference between the U. S. and Japan is that American scholars have experience in working at several different institutes as postdocs when young.

MUKOYAMA: The organization of universities and the employment system in Japan are quite different from that of the U. S. So it might be rather difficult to institute this system in Japan, but I wish that young people in Japan would aggressively challenge the present lack of a postdoctoral system in Japan.

#### - "LET'S HOLD AN INFORMAL MEETING FOR EXCHANGE OF IDEAS"

INTERVIEWER: It has often been stated that an exchange of ideas among scholars in different fields is desirable. What are your opinions about this?

HAYAISHI: The Gordon Conferences in the U. S. serve this purpose. I occasionally attend these conferences which take place at small boarding schools. I am with young scientists and after being asked many questions, I feel exhausted. In talking with young chemists, I find that many of their questions are off the point, but once in awhile, maybe once out of a hundred or a thousand times, I get a good idea from them. It is too bad that we do not have similar opportunities in Japan. It would be wonderful if organic chemists who have an interest in biochemistry and biochemists who have an interest in organic chemistry could get together and talk freely. In Japan, this kind of gathering tends to be formal. I am often invited to meetings by chemists, but most of these occasions are special lecture meetings at large conferences where I cannot speak frankly.

MUKOYAMA: Close communication and exchange among workers in different fields would bring about innovation. What is taken for granted in one field may be new and innovative in another field. For instance, each research activity has its own peculiar experimental techniques. In this sense exchange is important, but it happens very seldom.

HAYAISHI: The necessity of such interchanges has been widely expressed, but they do not occur often in Japan.

MUKOYAMA: A celebrated scholar such as Professor Hayaishi could possibly organize such a meeting. A personal appeal by an organizer is the key to the success of such a meeting. If the meeting were to be organized on the basis of genuine study there would be no problem, but political considerations in many cases cause difficulty in holding such meetings.

HAYAISHI: In fact, the other day an interdisciplinary meeting of academics was held for open discussion at the suggestion of a certain scholar. Several researchers, such as Dr. Yoshimasa Hirata, an organic chemist; Professor Shosaku Numa, a molecular biologist; Director Takashi Sugimura of the Cancer Research Center and I participated. At the meeting, Dr. Hirata talked about a toxicant extracted from a creature similar to a coral which inhabits the sea around Okinawa. Dr. Sugimura brought back a sample and found that it has the effect of promoting cancer. Subsequent to the meeting, Dr. Sugimura told me that it had been a fruitful meeting. I think it was a wonderful opportunity to have such an interdisciplinary meeting with free discussion.

MUKOYAMA: Something new may develop as a result of such a meeting.

HAYAISHI: The record of the meeting will not be made public as the meeting was informal. I think the meeting brought out many intangible, but promising, ideas as well as immediately useful results.

#### - "PROBLEMS IN CHEMISTRY PROPER ARE UNLIMITED"

INTERVIEWER: Recently, there has been a trend for chemists to study living material and life processes.

HAYAISHI: Some eminent chemists sometimes say "problems in chemistry have been getting scarce while unsolved problems involving biochemical processes are abundant. So it is natural to drift into biochemistry." But I believe that problems specific to chemistry are unlimited.

MUKOYAMA: Of course, there are still many unresolved problems in chemistry. I think that there are an enormous number of problems which are not yet clear and which should be worked on.

HAYAISHI: Researchers should choose a topic in which they are interested and study whatever they like. However, I have the impression that Japanese stick to one field. It is very common in Japan to think that one should study only organic chemistry because he is a graduate of organic chemistry, or that one should not study anything except inorganic chemistry if that is one's major field. Foreign countries are much more flexible in this regard. Some of the Nobel prize winners known as molecular biologists were originally chemists. I myself majored in microbiology and worked as an assistant professor in a microbiology department in the U. S. I then became Director of the Department of Toxicology at the U.S. National Institutes of Health and it was only after my return to Japan that I became a professor of biochemistry.

MUKOYAMA: The advantages of going into a new field with different methodology seems to have been demonstrated in many different countries.

HAYAISHI: In the U. S. I know of a case where a person from the field of biochemistry was appointed as a professor of pharmacology. An extreme case was the appointment of a person from biochemistry as a professor of anatomy. In Japan, it is believed that a professor of pharmacology should have classical pharmacology training in order to make a suitable contribution to education. In Japan, it is frowned on if we want to pursue studies in a field different from the one in which we graduated. This makes it difficult to carry out interdisciplinary academic research in Japan.

MUKOYAMA: If an organic chemist were to begin to work in biochemistry, he might study it with a different point of view, and that might be advantageous.

HAYAISHI: Recently, molecular biology has become extremely popular, and young people tend to deemphasize chemistry if they are interested in biochemistry. But they don't seem to have sufficient knowledge of chemistry. I think that those who want to pursue studies in biochemistry and molecular biology should have a fundamental knowledge and understanding of organic chemistry. It seems beneficial for my students to be trained in your department. But I'm afraid they might develop much more interest in organic chemistry and would not come back to biochemistry.

#### - "ORGANIC CHEMISTS HAVE VIVID IMAGINATIONS"

MUKOYAMA: Has the correlation between structure of chemotherapeutic agents and the mechanism of their action been made clear to any degree?

HAYAISHI: Some correlation has been made clear, but not completely. This is a characteristic of biochemistry. Some correlations have been made that are as clear as any logical explanation in organic chemistry. At present, however, most important discoveries in biochemistry are still empirical and are based on accidental discoveries. But structure and function are interrelated, so if we focus our attention on function too much without understanding structure, the truth will not become evident and the level of understanding may be as low as that of Japanese weekly magazine articles.

MUKOYAMA: New medicines can be discovered based on a fundamental understanding of molecular structure.

HAYAISHI: This is correct. In Japan, chemicals similar to already existing medicines are often synthesized to reduce toxicity, to accelerate absorption or to promote efficacy. But this does not lead the way to the development of radically new drugs. What happens is exactly the same as when Canon produces a camera slightly better than one produced by Leica, but does not produce a camera based on a completely new principle in which an entirely new concept is used.

MUKOYAMA: Organic chemists are imbued with images and forms and structures of molecules, so they should be able to suggest interesting chemotherapeutic chemicals. By using their imagination, they might come up with a certain molecule which might be effective therapeutically.

HAYAISHI: Recently it has become clear that substances which are completely different in appearance can be bonded to the same receptor not by classical chemical structure but by very intricate binding including minute solid structures. Simple examples

are endorphin and enkephalin. One substance is morphine and the other is a peptide, but both of them react with the same receptor.

- "FUTURE PROBLEMS IN ORGANIC CHEMISTRY"

HAYAISHI: Would you point out the future problems in organic chemistry?

MUKOOGAMA: I cannot talk about organic chemistry in general, but the main problems in the future in my field of synthetic reactions will be how to learn how to control reactions and how to selectively synthesize what we are aiming at with the use of fairly simple reagents. We are suggesting the concept of "synthetic control" but the object of research by organic chemists is to attain a means of controlling synthetic reactions by the organic chemical method.

HAYAISHI: What about enzymatic synthesis of materials?

MUKOOGAMA: That is now regarded as an important field. Enzymatic processes are now actually used in synthesis. If there are ten stages of a synthetic process, ordinary synthesis may be used in nine stages and a characteristic enzyme may be used in the tenth stage. This is a very popular procedure and is a very important field which we should continue to investigate in the future. But we would like to contrive new reactions competitive to enzymatic reactions for the specific stage which now requires enzymes.

HAYAISHI: Since our knowledge of organic chemistry is limited, we tend to use enzymes. Besides, most biologically active substances are unstable. For instance, if a carcinogen enters a body, it will turn to unstable epoxide and prostaglandin is synthesized via endoperoxide. As their half lives are less than one minute at room temperature and in a neutral condition, we cannot store them. They must be made as needed and utilized right away. That's why, in most cases, we don't generate chemically but generate specifically with enzymes.

- "ADVICE FOR YOUNG PEOPLE: EXPERIMENTS RATHER THAN THEORY"

INTERVIEWER: Finally, I'd like to ask what advice you have for young readers who are about to start carrying out research.

HAYAISHI: Although Japanese traditions and customs make it difficult to give such advice, I can state that it is good for young workers to receive training in excellent and in different research institutions. They should exchange opinions frankly and freely with senior workers. They should devote themselves to research which is of international interest. They may have some complaints as they work, but in terms of expenses for research, facilities, and academic clique issues, conditions are improving. I expect that there will be a Japanese Nobel prize winner in chemistry in the next generation. (Editor's Note: To date there have been three Nobel prizes awarded to Japanese for work done in Japan, Yukawa and Tomonaga in physics and Kawabata in literature. Esaki, born and educated in Japan, was awarded in the Nobel prize in physics for work done in the United States.)

MUKOOGAMA: It is a disadvantage to think negatively. By undertaking work with a positive attitude, researchers can do something interesting independently, and then they will be given further opportunities. Their work will be watched constantly.

INTERVIEWER: Japanese are said to be shy or unaggressive. Could you make some comments about this?

HAYAISHI: This is certainly true. Graduate students in foreign countries are not in awe of their teachers and they courageously ask many questions. I have had a number of opportunities to deliver lectures in foreign countries and I have felt rewarded for my efforts in terms of the reactions obtained. Opinions and criticism are expressed honestly. In Japan, sometimes we get into a useful discussion, but most people raise formal questions. It is the foreigners who challenge arguments in most cases, and who ask questions which are off the beaten track.

MUKOYAMA: Japanese are certainly shy. There is another big difference between Japan and foreign countries. Although Japanese are shy, there may also be a language barrier.

HAYAISHI: The language barrier has hindered Japan in its research. Whenever I go abroad, I ask myself again and again why are Japanese so poor at speaking English, including myself. The Japanese seem to have no aptitude for language (Editor's Note: linguistics). We should train ourselves to express opinions even if it has to be in broken English. Young people should not worry about giving a poor impression or seeming to be disrespectful by asking questions of anyone including senior scientists.

MUKOYAMA: With the exception of the language barrier, young Japanese people tend to express their opinions much more frankly and to carry on discussions more skillfully than they used to. I might say that young people express their opinions aggressively when discussing research.

HAYAISHI: It's not so bad in the case of a small or friendly meeting, but young Japanese people are still reserved in large conferences. I am impressed with how much young people know and understand. Students in the Faculty of Medicine are geniuses (Editor's note: in Japan the term genius is used to describe someone with an excellent memory) and they have computerized brains and can memorize textbooks. They have been educated this way starting with elementary school. On the other hand, they know nothing about what creative studies are. Nevertheless, they aspire to be researchers. Therefore, when I get new students I train them initially by letting them suffer by carrying out research experiments because such "geniuses" tend to neglect experimentation.

MUKOYAMA: Research cannot be accomplished just by spending time in a research laboratory from early morning till late evening. A research project should be designed to seek innovation and does not necessarily depend for its success on how much time is spent on it. Knowledge learned about fundamentals should be stored in order to pursue innovation.

HAYAISHI: When taking skiing lessons, information acquired from books on Christianity turns or about the quality of skis does not help us learn how to actually ski on the slopes. One might master swimming much more quickly by being drowned and forced to swallow water than by reading about how to swim. The more brilliant the students are, the more knowledge their brains are filled with, the more embarrassed they are to put it to practical use because they have not carried out any experiments. In biochemistry, they should continually carry out experiment after experiment. A Nobel prize winner, Professor Warburg (Editor's note: Otto Warburg, 1883-1970, German biochemist, was awarded the 1931 Nobel prize in medicine and physiology for his discovery of the nature and mode of action of the respiratory enzyme) gave advice to experiment uninhibitedly (Editor's note: the word uninhibitedly appears in English in the manuscript). In any case, carrying out experiments is fundamental.

- "RATHER THAN BEAUTIFUL FLOWERS FLOATING IN THE RIVER...."

MUKOYAMA: Experiments are what we can depend on. It has been said that those with great understanding became knowledgeable by reading papers. They can identify the source of innovation in papers so they themselves don't need to carry out experiments. Since we do not have such deep understanding, do not read papers as carefully as such people do, when a new idea occurs to us, we immediately begin to experiment with great enthusiasm. Sometimes such an experiment brings forth a new bud and we get it to sprout in an unexpected direction. Research in chemistry cannot be pursued without using our own hands.

HAYASHI: I am happy that as intelligent a person as Professor Mukooyama pointed this out. It is not necessary to be smart to study biochemistry.

MUKOYAMA: I am surprised to hear you say that. It is best if persons with a good understanding devote themselves to experiments. Therefore, I make an all out effort to tell young people to use their own hands in experiments. Fortunately, in my research laboratory, young students are trained by what are known by the Japanese as strict "devil sergeants" (Editor's note: senior researchers).

HAYAISHI: Whenever I have an interview like this, I return to my laboratory afterwards in the evening. This evening, I am going to tell my students what you said today, and I am certain that they will be inspired. This will be a good gift for them from me.

MUKOYAMA: When young, I was often advised not to do research on a popular subject. Unless we pursue our original research so that it will be appreciated forever, the work is meaningless. Research should not be like beautiful flowers floating on the surface of a river one day and gone the next, but should be like flowers which are firmly rooted on the bottom of the river and which live there the next day and the day after. This is the principle on which I work. There are many topics available in organic chemistry which catch the public fancy and attract attention. But workers should have a firm belief that the research they undertake is apt to bring out something new and original. Otherwise, they will be lured into doing something easy. It would be terrible if they feel satisfied with doing work which results only in a slight modification of someone else's work.

HAYAISHI: Of course, it is important to work on already established fields, but I'd like young people to establish their own fields of interest.

MUKOYAMA: Young people laugh at me whenever I tell them that research should be pursued with a firm conviction of ultimate victory. But I certainly believe this. I am not pleased if they say "we will try." Unless they say "we are certain to succeed," they will not succeed. Researchers grow if they learn something through what they themselves pursue. From the standpoint of a leader, it is important to praise young research workers even for a trivial accomplishment to help them acquire confidence. Do you visit your research rooms?

HAYAISHI: I, myself, am too busy to carry out experiments. But I make an effort to talk to each of my students as long as time permits, or I discuss their data with them.

MUKOYAMA: As I am still an inexperienced senior worker, I visit the research laboratory three times a day. The first thing in the morning I say "good morning" to my students and hold a discussion if necessary. In the afternoon and again before leaving for

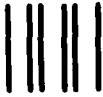
home, I visit them in order to keep in touch with them as much as possible. I think we can encourage young people to devote themselves to research by slapping them on the shoulder to convey our constant expectation and interest in them. They would be even much more impressed if a great scholar such as Professor Hayaishi would say a few words to them.

HAYAISHI: Since I am not very wise, the only thing I could do for them is to slap them on the shoulder too. (Editor's note: this is a typical Japanese remark expressing modesty.)

MUKOYAMA: This kind of activity keeps us young.

INTERVIEWER: Thank you very much for your useful discussion.

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